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Team leader strategies for enabling collaboration technology adaptation: team technology knowledge to improve globally distributed systems development work

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Abstract
Active management of team adaptation of collaboration technologies offers an important lever for influencing success rates in distributed project work, particularly in settings characterized by high task interdependence, such as information systems development (ISD). Substantial uncertainty exists as to how a leader might influence such technology adaptation during project work. Prior research indicates that a major leader resource to accomplish technology adaptation in these settings would be team technology knowledge (TTK). This empirical field study develops a five-factor model of strategies regarding awareness of TTK that team leaders take in intervening to affect technology adaptation in distributed ISD projects. The analysis indicates insights into when and why these strategies are effective and how they relate to each other as well as the leader's awareness of TTK. The study provides a way for ISD team leaders to approach improving team collaboration from a socio-technical perspective as well as insights into potential levers for improving team technology adaptation and the efficacy of ISD projects.
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Introduction

A growing body of empirical literature asserts that formation and usage of shared knowledge among team members critically enables effective execution of large, distributed information systems development (ISD) efforts (Beranek *et al*., 2005; Kotlarsky & Oshri, 2005; Espinosa *et al*., 2007; He *et al*., 2007; Yang *et al*., 2008). Whereas, large distributed ISD efforts require coordination of team efforts to succeed (DeSanctis & Jackson, 1994), shared team knowledge ('team knowledge') enables such coordination (Kotlarsky & Oshri, 2005; Espinosa *et al*., 2007; Yang *et al*., 2008). Interestingly, these studies raise an unanswered question central to current research on ISD and the impact of technology, namely, how does one interpret and use knowledge such as team knowledge during ISD efforts, or, how does a project leader move to a socio-technical perspective when implementing new IT in organizations (Doherty & King, 2005).

ISD teams provide an interesting microcosm in which to explore how a leader might interpret and apply awareness of team knowledge of

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technology. Globally distributed ISD teams face high difficulty in coordinating outputs and enabling collaboration (Walz *et al.*, 1993; Xia & Lee, 2004; Kankanhalli *et al.*, 2007). The leaders are constrained in their access to team members' activities and influencing them, which makes the ability to connote ideas and motivate changes in behavior critically important for effective leading (Walvoord *et al.*, 2008). Together these notions become particularly intriguing considering that computer-mediated ISD team settings benefit from active leader facilitation to achieve maximal results (Nunamaker Jr. *et al.*, 1987; Miranda & Bostrom, 1999). A recent study has indicated that a team's collective computer efficacy, their belief in their ability to use computers, influences outcomes of Virtual Team (VT) projects (Fuller *et al.*, 2006). As such, we can expect that a team leader effectively understanding team technology knowledge (TTK) and employing it would be able affect improved usage of technologies for collaboration, leading to better team outputs.

Evidence points to ISD team leaders engaging technology facilitation to affect on-going improvements in the designs of their teams (Thomas & Bostrom, 2008). This makes sense, since we know that both design efforts and on-going coaching are needed to get teams to maximize their performance (Wageman, 2001). The leadership in distributed settings poses new challenges for leading, such as a need to learn how to monitor and exert presence (Lyons *et al.*, 2009), and carefully designed software might facilitate these leadership roles and enable distance teaming (Zigurs, 2003). Researchers have proposed that leaders will need to manage the collaboration technologies (CTs) to fit tasks and create structures and routines to handle the interdependencies in ISD (Bell & Kozlowski, 2002) and that effective teams will need leaders who can dynamically engage in these tasks when 'goal-frustrating' events occur during projects (Zhang *et al.*, 2005; Schiller & Mandviwalla, 2007; Wakefield *et al.*, 2008). These propositions remain largely untested (Wakefield *et al.*, 2008). In particular, it would be useful to know how leaders may approach the on-going management of CTs in distributed team settings for maximal benefit.

We identify and explore how team leaders in the field perceive, use, and develop team knowledge of CTs to influence technology usage and improve team interaction during distributed ISD teamwork. Specifically, this paper addresses three research questions:

1. Regarding CTs, what strategies do team leaders take to get teams to use them?
2. How do these strategies relate to leader understanding of TTK?
3. How does team leader awareness of TTK relate to effectiveness of interventions pursuing the various strategies?

This study identifies a five-factor model of ISD team leader strategies for achieving successful implementation of CTs within their teams. These strategies provide insight into how larger ISD efforts may analyze organizational knowledge of technologies and integrate that knowledge within designs of ISD projects to achieve an improved socio-technical approach.

The paper begins with a discussion of related research, proceeds to describing the methodology employed, and concludes with an analysis of the data collected. Implications are presented in the discussion section at the end.

Adapting technology during teamwork

A substantial body of literature has confirmed that the use of CTs in work teams requires on-going adaptation of the CTs in order to effectively structure interaction to enable productivity (Orlikowski *et al.*, 1995; Majchrzak *et al.*, 2000; Easley *et al.*, 2003; Poole & DeSanctis, 2004). Technology adaptation in VTs has most commonly been defined from the perspective of adaptive structuration theory (AST) (Schiller & Mandviwalla, 2007) and refers to modification of features and ways of using CTs. AST holds that groups initially appropriate one or more CTs and later adapt them *during* their work (DeSanctis & Jackson, 1994). We employ AST as a broad framework for analyzing the activities of VT ISD leaders herein, as AST provides a comprehensive framework for effectively capturing the necessary elements of interaction (Bostrom *et al.*, 2009) and it is the most applied comprehensive theory for understanding VT inputs processes and outputs (Schiller & Mandviwalla, 2007). AST-based research has shed light on why teams engaged in longer, on-going projects must adapt their CTs during work. As teams use CTs, structures develop (Majchrzak *et al.*, 2000). These structures are ways of using and understanding the CTs they have. These structures constitute both constraints and resources for collaborating.

To illustrate, in one case found in this study, sub-groups within a team had differing email structures. In one team, email was an informal tool used daily for quick chatty notes. In the other, it was reserved for exchanging files. The two groups were joined in one development effort and after several months, as the teams began to get frustrated with each other over violations of the constraints each related to email, a discrepant event occurred. Discrepant events occur, events in which structures prove inadequate for teamwork (Tyre & Orlikowski, 1994; Majchrzak *et al.*, 2000).

On these occasions *teams engage in adaptation* to improve interaction. That is, they adapt the ways they use CTs and which CTs they use for which tasks in order to get around existing constraints and/or take advantage of unrealized opportunities. In as much as CTs constrain and enable the possible communications behaviors of a VT member, evidence indicates they will impact trust in high task interdependence contexts such as ISD (Rico *et al.*, 2009). Once teams adapt into new usage patterns, new structures form, presenting modified constraints and resources. Structures may lead to need for adaptation in the case that a resource is lacking of a type of interaction is too constrained and adaptation leads to new structures as new forms of usage settle into patterns, a cycle of *reciprocal causation*. AST's reciprocal causation has caused researchers some degree of difficulty in parsing and studying adaptation, as clear sequences of causation can be difficult to parse. Nonetheless, this cyclical process of mutual influence in IS change has been identified as a critical component one must consider to understand how groups assimilate and use IS (Lyytinen & Newman, 2008), and collective beliefs about ability to use CTs also proves to influence project outcomes (Fuller *et al.*, 2006). Thus, team knowledge of technology would likely influence any imposition of new CT routines, features, or packages.

Team knowledge of CTs

Just what would a team share as knowledge of CTs? Technology structures ultimately exist as shared cognitions among members of a group (Giddens, 1984; Poole & DeSanctis, 2004). Venkatesh (2003) found that *individual* cognitions, specifically, expectations about performance, effort required, social influence, and facilitating conditions (organizational and technical infrastructure supporting use), shape the ways team members will form intentions as they adapt post-adoption usage of CTs. *Collective, general* team beliefs about their ability to use CTs also enable VTs to achieve their goals (Fuller *et al.*, 2006). Research on team knowledge helps clarify which specific types of cognitions affecting technology adaptation might be shared among team members.

Theory of team knowledge explains that key coordination-enabling shared understandings among team members relate to technology, team, and task (Cannon-Bowers *et al.*, 1993). This study's particular interest regards shared understandings of technology in relation to CT interventions. Thus, it focuses on how TTK may be perceived by a team leader and relate to successful interventions.

The TTK consists of shared understandings in three areas: (1) how a technology operates and what features it has, referenced herein as 'functions and usage', (2) how a technology may fail and predictions about when it may fail, referenced herein as 'future prediction', and (3) how to apply technology and make it useful in a given work context, referenced herein as 'usefulness' (Cannon-Bowers *et al.*, 1993; Mathieu *et al.*, 2000). To the degree that adaptation of CTs resembles adoption of CTs, technology acceptance theory should help clarify successful adaptation. In technology acceptance theory four individual cognitions listed above shape usage (Venkatesh, 2003). While, this is a conjecture to be explored in future research, these types of technology-adoption-relevant cognitions might help highlight which pieces of TTK may have the most salience for successful interventions. For example, we can attempt to logically map them onto the dimensions of TTK. Individual cognitions about effort expectancy integrate issues related to ease of use and complexity of a CT and could be influenced by shared understandings about the functions and usage of a CT. Individual cognitions about performance expectancy integrate issues related to outcome expectations, relative advantage and could be influenced by shared understandings about usefulness. Individual cognitions about facilitating conditions integrate issues related to how a CT will be supported and effective due to technical and organizational support, related to team knowledge of future prediction.

Researchers have found empirical support for the value of team and task team knowledge in team adaptation and coordination (i.e., Swaab *et al.*, 2002; Waller *et al.*, 2004; Kotlarsky & Oshri, 2005; Espinosa *et al.*, 2007; Yang *et al.*, 2008). Waller *et al.* (2004) found that shared team task knowledge became a critical differentiator between high and low performing teams during non-routine tasks. Swaab *et al.* (2002) found that shared team knowledge of technology enabled members to trust perceptions of reality (converge on data interpretation), leading to increased team cohesiveness and better negotiation capabilities. Another study identified task and team member shared knowledge (explored through transactive memory and rapport) as enablers of distributed team success (2005). Finally, among these studies that have controlled for the technology used by their sample groups so that there would be minimal variance in TTK, Yang *et al.* (2008) found that team member shared knowledge can be developed and leads to higher performing teams.

One team knowledge study did not tightly control and limit CTs to a single system or a very short experimental timeframe (Espinosa *et al.*, 2002). This study found the presence and usage of a specific software configuration management system (SCMS) outweighed effects of other forms of task and team shared knowledge. While the authors presume this is in part due to the embedded task knowledge in the SCMS, this result supports the presumption that the structures embedded in the SCMS and existing in TTK regarding the SCMS at least partially explain the effect they found. While we find no existing study that has specifically targeted TTK management by team leaders, Espinosa's finding empirically supports the notion central to this study that leaders will benefit from specific awareness of TTK in intervening to improve team interaction and coordination.

Managerial interventions in team technology adaptation

Managerial or leader interventions to improve team usage of technologies during on-going work have received limited attention in prior research. Researchers studying a variety of topics related to team interaction in distributed, computer-mediated contexts continue to indicate a need for specific focus on studying technology adaptation interventions during the process of collaboration. Examples of such supporting research include studies of technology adaptation (Majchrzak *et al.*, 2000), communication and trust (Jarvenpaa & Leidner, 1999; Kayworth & Leidner, 2002), shared understanding of CT (Leidner & Kayworth, 2006), conflict resolution (Sherif *et al.*, 2006), teamwork quality (Easley *et al.*, 2003), and knowledge conversion (Massey & Montoya-Weiss, 2006). Overall, little research has examined how leaders of work teams might go about the informed management of CT adaptation in on-going, large, global ISD teams.

Five goals of technology adaptation intervention

Why would a leader engage in a technology adaptation intervention? Research on change involving CT adaptation indicates that the purpose of a change may impact the appropriate design of an intervention and course a change takes (Orlikowski & Hofman, 1997). Also, facilitation studies have shown that interventions in content *vs* process emphasis (Clawson & Bostrom, 1993; Miranda & Bostrom, 1999) or unclearly defined goals (King *et al.*, 1996; Griffith *et al.*, 1998) may negatively impact results. Thus, goals of an intervention will influence a leader's approach and efficacy. This study draws on research from both technology adaptation and shared team knowledge literatures and identifies five key intervention goals.

From the technology adaptation literature, research on computer-mediated teams identifies outcomes related to CT adaptation and usage as process losses and gains (Nunamaker Jr. *et al.*, 1996), and researchers have found somewhat conflicting results regarding whether CTs innately cause gains or losses (Fjermestad & Hiltz, 1999; Fjermestad & Hiltz, 2001), supporting the proposition that the specific conditions of the CT usage process critically impact CT usefulness (Reinig & Shin, 2002).

In distributed, computer-mediated teams, research suggests two central process outcomes relating to effective CT usage: (1) conflict, a process loss (Kankanhalli *et al.*, 2006; Wakefield *et al.*, 2008), and (2) knowledge conversion, a process gain (Majchrzak *et al.*, 2005a, b). While some evidence suggests that productive conflict may exist in group work with regard to substantive or task conflict management under narrow conditions (Jehn, 1995; Amason, 1996), other more recent empirical research on ISD projects indicates that overall, intra-team conflict has a negative impact on team productivity (Barki & Hartwick, 2001) while effective usage of CTs can avoid conflicts and build trust (Rico *et al.*, 2009). Managing conflict in order to minimize it would lead to better outcomes, and the specific CT usage of the team can enable better conflict management depending on the process of CT adaptation (Chidambaram *et al.*, 1991; Kankanhalli *et al.*, 2006).

Knowledge conversion forms another core goal. Knowledge conversion involves transmitting and recreating knowledge from one individual to others in a team. Distributed teamwork involving highly interdependent tasks requires computer-mediated knowledge sharing and processing capabilities (Lipnack & Stamps, 1999). The representation of knowledge will intrinsically be impacted by the forms and choices available in the CTs (Daft & Lengel, 1986; Zack, 1993; Dennis & Valacich, 1999), and the form of knowledge objects and perceptions of them can impact their usefulness in the differentiation and integration of knowledge (Carlile, 2002; Bendoly & Swink, 2007; Walvoord *et al.*, 2008). It follows that knowledge conversion constitutes a central process gain possible from effective CT adaptation and usage (Massey & Montoya-Weiss, 2006). A shift in the CTs used by team members may provide leverage for improving knowledge conversion.

While conflict management and improved knowledge conversion represent two core goals leaders may have in intervening from the perspective of technology adaptation, research in team knowledge suggests three coordination goals leaders may set. These are technical, temporal, and process coordination goals (Espinosa *et al.*, 2007). We included these in our analysis because they have proven useful in understanding shared team knowledge effects in prior work looking at team knowledge. Thus, we extrapolated that they may be important for understanding the value of TTK. As they are well-defined in prior, recent work in this area, we refer the reader to their source for in-depth description and development (Espinosa *et al.*, 2007).

Actions during technology adaptation intervention

Succinctly and meaningfully classifying the actions taken by leaders during their technology adaptation interventions would enable improved guidance to leaders in the field, yet this domain remains an emerging area of academic interest characterized by some uncertainty about how actions impact VTs. One study identifies leader actions in distributed software settings as broadly related to either behavioral control, such as enforcing rules and setting policies, or resource provisioning, such as providing tools and interconnections among team members and resources. Behavior control actions often lead to unintended negative consequences (Piccoli & Ives, 2003). Thus, presence of behavioral control actions may explain negative results while resource-provisioning actions may help explain positive results, and both impacts may be specifically related to the strategy or goals of the intervention.

At the same time, another study has found that line managers themselves perceive the role of behavioral control to be the most important in virtual settings (Konradt & Hoch, 2007). Two other studies suggest that behavioral control actions evidenced by task monitoring and reporting may be important keys for success (Carte *et al.*, 2006; Wakefield *et al.*, 2008).

Substantial uncertainty remains as to how VT leaders should act in managing the on-going collaboration in their teams to best achieve successful outcomes, though some literature indicates this is a needed role on the part of leaders (Beranek *et al.*, 2005; Zhang *et al.*, 2005). Leaders may enable their teams by delegating responsibilities so that the team may self-manage, and they can facilitate team interactions. They need to understand the competency levels of team members in order to make these delegations and facilitations more effective (Zhang *et al.*, 2009). By knowing how leaders perceive TTK and use that perception to affect better usage of CTs, they may more effectively understand their team members and use that understanding to lead their VTs.

Methodology

Previous AST studies of technology adaptation have employed four main methods (Poole & DeSanctis, 2004): case study (e.g. Maznevski & Chudoba, 2000), observation (e.g. Majchrzak *et al.*, 2000), experiment (e.g. Gopal *et al.*, 1993), and surveys (Salisbury *et al.*, 2002). To understand how leaders influence technology adaptation and perceive TTK, the characteristics of observation best fit this study's needs.

Observational AST studies take a constitutive interest in understanding what actions actors, such as team leaders, take on a microlevel to positively influence the development of new ways of using technology. They enable researchers to parse the events occurring during adaptation. One example of this sort of research applied critical incident technique (CIT) to observe how leaders build trust (Thomas & Bostrom, 2008). Observation studies require a narrowing of focus in order to control the quantity and nature of data collected on adaptation events. This has typically been accomplished by employing one or both of two common means: (1) using students as a sample, or (2) using a single, predetermined technology (often email or a group support system). A third innovative and notable but rare control method uses a long-standing relationship enabling pervasive access to a single group's process during team interaction on a single project (e.g. Majchrzak *et al.*, 2000).

In order to observe leader actions without controlling for technology *while also* observing in the field *and* observing multiple leaders in multiple, distributed contexts in order to observe patterns across contexts, CIT provided a solution. CIT is a robust research methodology from the industry/organizational psychology field designed for isolating individuals' behaviors in performing specified job roles using self-reported retrospective data. CIT provides a means to intensively observe VT leader actions in real-life contexts without any manipulation while employing retrospective data (Flanagan, 1954; Kelly & Bostrom, 1998). CIT has been successfully applied in more than 1000 published studies, particularly in the field of industrial and organizational psychology and including management and information systems studies (Kelly & Bostrom, 1998; Fivars & Fitzpatrick, 2001; Butterfield *et al.*, 2005). Within CIT studies, actions are gleaned from analysis of critical incidents. A critical incident is an occasion involving a prescribed role carried out particularly well or poorly, which led to definite, substantial impact on the process surrounding it and the outcomes from that process (Flanagan, 1954). Actions and their consequences emerge through the analysis of multiple examples of individuals engaging in the same role across multiple contexts, thereby ensuring general applicability to the role (Andersson & Nilsson, 1964).

When CIT studies focus on a somewhat rare job role, such as a sub-role like technology adaptation management, interviews are appropriate with approximately 50 critical incidents being an adequate sample to ensure coverage of the major dimensions within the sub-role (Flanagan, 1954; Hopkins, 1987). To be sure, the logic behind these replications in CIT approximates case method replication rather than population sampling, in that the replication goal is to describe fully the nature of a phenomenon rather than assess its prevalence in a population (Yin, 2003).

Critical incidents of technology adaptation intervention are occasions in which a leader remembered taking action to influence his or her team's usage of one or more CTs in order to improve team interaction (whether it was failing or not) and could report exactly what impact the actions had on CT usage, team interaction, and the ultimate team project outcomes.

Leaders qualified for the study had to have at least 2 years of distributed ISD team leadership experience to ensure that each interviewee would have had at least one experience of consequential technology adaptation management. To maximize identification of successful interventions this study targeted sampling of high performing leaders, requiring interviewees to show signs of success as VT leaders. These qualifications included self-reported as well as observable measures, such as evidence of promotion, titles, or awards for their work as virtual team leaders. Two rounds of pilot interviews to refine the protocol with practicing leaders indicated that leaders actually had more consequential experiences with technology adaptation management than expected, approximately four per 2 years and that leaders would sit for an interview of up to about 2 h. The protocol was designed to collect all four of these critical experiences within 2 h.

Thirteen leaders qualified for the study out of 20 screened. Their virtual team experience drew from a variety of firms conducting ISD projects, six of them top-rated IT consulting firms (McDougall, 2005). The researchers conducted 2-h structured interviews with the leaders and collected tabulated background data. A listing of the primary interview questions is included the appendix. The sample met the target of collecting at least 50 critical incidents for replication purposes, ending up with 52 critical incidents of technology adaptation management. These incidents derived from 30 different ISD projects with a median project length of 1 year, median monthly budget of $625,000, median team membership of 30 people, and a median of four organizations in at least three countries representing at least two different continents involved.

The median interview length was 2 h and 10 min. The transcribed incidents filled 510 pages typed. Each transcript was reviewed for accuracy by the corresponding interviewee. Then, follow-up unstructured interviews were conducted to gather feedback on the data and explore any unclear references or interesting observations.

Findings

Five strategies for technology intervention

To address the first and second research questions, open coding of all 52 incidents helped identify how leaders were manipulating the CTs of the team. Five coders separately coded the data, two internal to the project and three external, to identify salient characteristics of the leader actions taken during the interventions. The two internal researchers then engaged in a follow-up round of coding of these actions to identify the strategies taken. Five main strategies emerged by consensus.

These five strategies were as follows:

1. Switching; when a leader acts to switch the team from one existing CT to another with identical usage expectations and features due to availability or reliability problems with an existing CT, it is a switching strategy.
2. Expanding; when a leader acts to expand team usage of an existing CT into an additional work context in which it will be used in the same way it has already been used by (at least mostly) members of the team already using it, it is an expansion strategy.
3. Merging; when a leader acts to get sub-groups within a team to merge their similar usage of similar, but perhaps incompatible, tools into a single CT, it is a merging strategy.
4. Modifying; when a leader acts to block a type of usage of an existing CT or to add a new feature set requiring new interaction behaviors to an existing CT, it is a modification strategy.
5. Creating; finally, when a leader acts to get team members to use a new CT with new features to enable new interaction behaviors, it is a creation strategy.

These five strategies have been added to the coding scheme with the *pro forma* codes in the appendix for ease of reference and to enable future researchers examining similar phenomena.

Exploiting and developing TTK in interventions

Of the 52 intervention incidents, 23 displayed a single, primary strategy and complete data regarding leader actions, awareness of TTK, and intervention goals. Analysis of these interventions with a single strategy enabled isolation of any unique effects relating to awareness of TTK due to the individual strategies to address the third research question. Thus, the other 29 incidents were excluded from the data. The coding scheme listed in the attached appendix classified each intervention. In examining the coding scheme in the appendix, note that coders coded the results of the interventions as either successes or failures based jointly on self-report by the practitioner as well as criteria drawn from AST concerning whether the leader reports team members faithfully appropriating the CT targeted.

One of the authors read through the critical incidents and found matches. These were later discussed with a second coder during the analysis phase in coming to a consensus on the specific, clear presence of the codes in each incident and on the result of each intervention. During this coding process, coders were also asked to identify which strategies best exemplify using pre-existing awareness of TTK in intervening *vs* developing such awareness. Switching and expanding strategies were associated most clearly with exploiting while merging, modifying, and creating associated most clearly with developing (respectively ordered on a continuum from straight exploitation to development).

Exploiting TTK during intervention

In seven incidents leaders indicated action choices based on their awareness of a technology already being in use by members in their team and being readily understood by and available for use by the complete team (Table 1). In the first incident, for example, each of the team members had been trained on the audio conferencing technology. They were using it among their sub-groups and for whole-team interaction. The leader reported that they had a clear, shared understanding of how the tool functions, its capabilities (functions and usage), and how to use it to contact each other to complete specific parts of their work (usefulness).

The leader indicated awareness that team members were refusing to use the CT with each other, and this refusal was leading to deepening issues between the two non-collocated sub-groups. There was a cooperation problem (conflict resolution goal). He chose to mandate and force use of the CT (rule supporting action). In this case, there was team knowledge about functions and usage. If TTK theory is correct, this pre-existing knowledge made it clear to all involved that the technology would function and would be readily available. Thus, the leader was able to draw on the team knowledge of the audio conferencing tool to influence behavioral change through the intervention and solve the cooperation problem between the two sub-groups.

Similarly, in incidents two, three, four, six, seven, and eight, the leader recognized a shared understanding of a tool already in use (incidents two, four, six, and seven) or of a tool for which a direct substitute was already understood (incidents three and five). He then made use of that shared understanding to enable the expanded use of the CT.

The leader in incident two provided a good illustration of how he was exploiting his awareness of TTK as he intervened. He was considering general team awareness about the functions and usage of email and that team members knew email would fail if used it as they normally do (future prediction):

> There were cultural issues to using the technologies. The technology was appreciated ahead of time. Email. We knew we were going to use it; however, the use of email was

Table 1 Exploitation strategy incidents/interventions

Incident number	Result	Strategy	CT(s) involved	TTK awareness			Support actions		Adaptation goal		Coordination goal		
				Functions and usage	*Future prediction*	*Usefulness*	*Training*	*Rule*	*Knowledge conversion*	*Conflict resolution*	*Technical*	*Temporal*	*Process*
1	S	Expand	Phone, audio conf.	X		X		X		X		X	X
2	S	Expand	Email, Wiki	X	X	X	X	X	X				X
3	S	Switch	Teamware	X	X	X		X	X			X	
4	S	Expand	eMtg	X						X	X		
6	S	Switch	Phone, audio conf.	X	X			X	X			X	
7	S	Expand	eMtg	X		X		X	X			X	X
8	S	Expand	Calendars, eMtg	X		X		X	X			X	X

Acronyms: TTK = team technology knowledge; CT = collaboration technology; eMtg = electronic meeting; IM = instant messaging; Conf. = conferencing; S = successful; F = failure.

different than you might use it in a smaller group where you're just talking with two collaborators.

As a result of this understanding, he communicated to the team why they should adapt (usefulness), and he chose to set up a content versioning system *accepting email submissions*, thereby exploiting the existing understanding of email for exchanging versions. This is an expansion intervention in that he did not require the team to use the new interface to access the system. In this way he exploited all three cognitive aspects of the existing email structure, modifying it invisibly in the process as team members now had a different transmission and retrieval flow and shared archive indicating the latest version of the code (though they did not have to use the archive). This incident points to the next section, developing and then exploiting technology structures during interventions, in that this leader did modify the team's email structure to a minor degree (the group 'to' address changed). Leaders pursued more of a developing strategy in 16 incidents.

The coding identified no discernable efficacy difference between knowledge, conversion, or conflict resolution goals in exploitation strategy interventions. Two successes classified as conflict management interventions, and five successes were knowledge conversion interventions. In agreement with facilitation research noted earlier that supports the notion that process facilitation is more important than content facilitation, it did appear likely that temporal and process coordination goals are more likely to fit with an exploitation strategy. Future research should explore this proposition by collecting a larger number of incidents targeted specifically to capture exploitation incidents within these categories.

Developing structures in an intervention

Distinct from the pure exploitation incidents just presented, in the remaining 16 incidents VT leaders acted to develop CT structure in order to then exploit it. The nature of change and depth of change present in the data suggested three varieties of developing strategies present: merging, modifying, and creating. In eight incidents the development strategy led to successful use and improved team outcomes (incidents 8 through 17). In another eight incidents development strategy applications failed (incidents 16 though 23) (Table 2).

Incidents 21 and 22 present a bridge between exploiting and developing strategies as they each involved an initial attempt at creating new CT usage but failed to create the desired new usage results. In 21, the leader reverts to Excel, the tool for which a CT structure exists, having attempted to add Microsoft Project in order to improve the team's ability to share knowledge and manage their project. In 22, the leader learns the CT structure among a sub-group and adds it to the requirements for the project management to take advantage of it, thereby exploiting the use of their CT structure in the team by bridging between their way of understanding

Table 2 Development strategy incidents/interventions

Incident number	*Result*	*Strategy*	*CT(s) involved*	*TTK awareness*			*Support actions*		*Adaptation goal*		*Coordination goal*		
				Functions and usage	*Future prediction*	*Usefulness*	*Training*	*Rule*	*Knowledge conversion*	*Conflict resolution*	*Technical*	*Temporal*	*Process*
10	S	Create	Email, FTP	X	X	X	X		X			X	
11	S	Create	IM	X		X	X		X			X	X
12	S	Create	eMtg	X	X	X	X	X	X				X
13	S	Merge	Email, IM	X			X			X			X
14	S	Merge	Teamware	X			X	X		X			X
15	S	Modify	Email	X		X	X	X	X				X
16	S	Modify	Wiki	X				X		X		X	X
17	S	Modify	Email	X					X				X
18	F	Create	OO tool			X		X	X		X	X	X
19	F	Create	Email, BB			X		X	X				X
20	F	Create	Phone, IM			X			X		[a]	[a]	[a]
21	F	Create	eMtg			X		X		X	X		
22	F	Create	OO tool			X			X		X		
5[b]	F	Create	PM tool			X		X				X	X
9[b]	F	Create	Email, phone, IM			X			X			X	X
23	F	Modify	Teamware					X	X			X	X

[a]No particular coordination goal could be identified.
[b]Incidents out of numerical order due to dual use during analysis.
Acronyms: OO tool = object-oriented development collaboration tool; BB = bulletin board; PM = project management; TTK = team technology knowledge.
Note: Shading indicates emphasis of a surprisingly consistent result.

the CTs and the rest of the team due to an existing lack of communication.

The sub-group had refused to use the common tools of the rest of the team, which had led to conflict. Both 21 and 22 had mixed results in that they initially failed and the adaptations did not go as planned. In 22, the leader did not take the next step of connecting the rest of the team to the non-communicative sub-group, resulting in a bottleneck. The sub-group never started using the email and phone CTs. Bridging through IM provided a band-aid measure, and ultimately, the team remained without communication between the sub-groups due to the lack of bottleneck throughput. In 21, the team never started using Project as desired. Reversion to Excel resulted in the same inefficiencies as before but at least a baseline of reporting, another temporary fix that did not solve the core problem.

A closer look at incident 21 reveals a bit more about the leader. In this incident, the leader apparently did not have a strong personal understanding (technology knowledge) of Microsoft Project. He did not know how it functions, what its limitations were, and could not predict how it would work and fail within the team. His attempt to get the team to use Microsoft Project failed, leading to frustration and lost time. In the meantime, the leader was able to salvage the situation by recognizing an alternative CT for which there existed a CT structure among almost all team members. Viewing this incident, it seems likely that each individual CT may be considered in terms of its own structure within the team, and the leader must have an individual technological knowledge in each of the three areas for each CT in order to discover the structures and use them effectively in managing their adaptation. As a proposition for future research, the most effective leaders in large-scale distributed project settings will be the leaders with more complete individual knowledge of the functions and usage, future prediction, and usefulness aspects of the CTs used by their teams.

In eight incidents, two successes (8, 10) and six failures (9, 18–22), the strategy was to create a CT structure among team members where there was no shared experience or knowledge of a CT. In four incidents, three successes (13–15) and one failure (23), the goal was to modify an existing CT structure. Two incidents (11, 12) involved merging CT structures held by two sub-groups within the team so that would use the same CT.

Merging TTK to form unified CT structures may be a simple, readily available solution to enable technology adaptation intervention, particularly for conflict resolution. Both incidents involving merges were successful (11 and 12). In 11 the team began by using the client's teamware portal suite. It quickly became apparent that the rules and resources within this teamware were unclear to the members of the team from other organizations, and they were difficult to learn and physically enable through reconfiguration. This resulted in conflict and deteriorated trust. The leader suggested the team move to his organization's teamware portal suite as a solution. They tried this too and ran into the same problems. He assigned a team member fulltime to research an alternative suite suited to the specific, common usage understandings of the team members and implement it. This worked. It appears from this incident that using the third-party solution not owned by any specific organization within the team may serve as a vehicle for resolving conflict and rebuilding trust.

In terms of TTK awareness by a leader, successful development interventions appear more likely to have taken into consideration the base understanding of how to operate the CT (functions and usage) (100% of the successes) and problem solve (future prediction) (two of the successes), while the failures seemed to skip this part and focus only on what the CT would do for the team members (usefulness) (half of the successes and seven of the eight failures), perhaps contradicting some IS literature that suggests the dominant importance of usefulness perceptions in motivating technology acceptance (Davis, 1989). It appears that usefulness may be important for individuals to experience and feel but not so useful for leaders during development interventions. The phrase 'show me don't tell me' comes to mind. Team members will create their own sense of usefulness apparently and need the leader to focus more on the functions and usage and future prediction when acquiring new CT(s) during teamwork.

In creation incidents 16, 19, and 20, technical problems emerged as the leader attempted to set up and run the new CTs and contributed to failure. These interventions show no indication of the leader focusing on the functions and future prediction aspects of the CT structure. If the leaders had had such awareness, perhaps the team members would have been able to help problem solve and to accept the difficulties more readily, as they did in successful creation incidents 8, 9, and 10. Existing end-user training literature supports this finding, adding that both motivation and ability to use CTs are understood as key core components for performance (Bostrom *et al.*, 1990). It appears leaders must be aware of TTK within the functions and usage dimension especially for successfully developing the CT ability of team members in creation incidents. This too is a proposition for future research.

In that development interventions imply a need for learning new CTs, it is not surprising that the successful incidents showed a strong likelihood to contain training supporting actions (six out of eight), while no failure incidents used training. While not surprising in concept, in practice this finding may be unexpected, since not all leaders took the time to conduct training during intervention. This finding helps clarify how behavioral control may negatively impact outcomes for leaders of these teams. In five incidents (9 through 13), all successes, the leaders assigned a training, pausing work, and had team members focus on developing their understanding of the CT being adapted. To put this training cost and result in perspective, the leader involved in failure incident 16 reported having to collocate key members of the team due to inability to get work done virtually. This ultimately cost more than $200,000 in direct expenses not to mention lost time. Training had far less cost. In one team, training meant simply conducting a virtual meeting in which the new CTs were shown and explained. Meanwhile, 'rule' supporting actions seem fairly evenly distributed across the success and failure incidents. This suggests that behavioral control actions still have a place but that the 'training' support actions have particular importance for affecting development strategy interventions.

A closer look at incident 8 (Email, FTP) indicated that the leader was thinking of the CT intervention as a process change impacting task and people in addition to adding a CT. There would now be exact check-in and check-out of code files along with follow-up calls to examine code changes. Representatives were assigned to a new role as FTP user liaisons. In incident 8, the leader engaged all three aspects of TTK. FTP had not been used within the team prior to the intervention. Although the team members were all 'techies' according to the leader, he did not assume that the individual understandings of FTP technology would match or convey all necessary information about functions and usage guidelines or understanding how the FTP tool would behave.

As a result he conducted training and had the users try out this FTP implementation prior to bringing it online for work. These characteristics of the intervention point to the development of a strong, shared FTP team knowledge. Having the shared knowledge appears to have enabled the successful adaptation of FTP during teamwork. The appropriation was so successful that the leader's company established a policy directing its use in future distributed projects in the way it was adapted in this incident.

Discussion

This study develops and presents five technology adaptation strategies that ISD project managers may apply to improve outcomes in distributed, multi-organizational, multi-cultural teams in order to improve team interaction and achieve better outcomes. These five strategies are (1) switch, (2) expand, (3) merge, (4) modify, and (5) create. Based on AST, the study's analysis indicates levels of disruption to existing technology structures in a team underlying the order of the five strategies. The strategies range from least disruptive of technology structure (1. expand) to most (5. create). Less-disruptive strategies appear to be more effective in general (Figure 1). As a result, an immediate implication for team leaders is that they should take greater care and implement additional supporting actions when attempting the more disruptive strategies.

An understanding of these strategies helps to fill an important gap in existing knowledge about how to integrate knowledge about how teams operate into systems development efforts (Doherty & King, 2005). It also adds to existing research need in the area of how leaders may intervene to improve teamwork in distributed

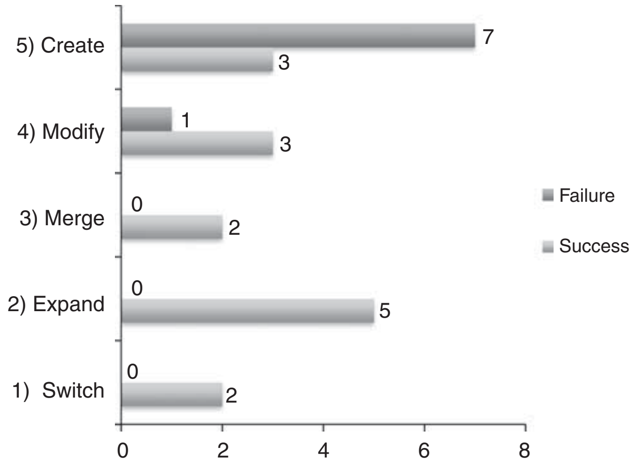

Figure 1 Number of success and failure incidents for each strategy.

Table 3 Incident success by strategy and TTK awareness

	No. of incidents	*Functions and usage*	*Future prediction*	*Usefulness*	*Total TTK[a] awareness (%)*
Success					
(1) Switch	2	2	2	1	83
(2) Expand	5	5	1	4	67
(3) Merge	2	2	0	0	33
(4) Modify	3	3	0	1	44
(5) Create	3	3	2	3	89
Failure					
(1) Switch	0	—	—	—	N/A
(2) Expand	0	—	—	—	N/A
(3) Merge	0	—	—	—	N/A
(4) Modify	1	0	0	0	0
(5) Create	7	0	0	7	33

[a]Total TTK refers to the total observed awareness of the team technology knowledge (TTK).

settings (Zhang *et al.*, 2005). The present study's findings indicate that VT leaders attempting to implement CTs in ISD teams will benefit from analysis and development of the TTK. Specifically, ISD project managers will benefit from better training on CTs in order to think of them within the three team CT knowledge areas: (1) functions and usage, (2) future prediction, and (3) usefulness.

The data indicate that understandings of TTK will enable leaders to choose less disruptive intervention strategies and make the more disruptive strategies more successful, thereby improving technology adaptation success and project outcomes (Table 3). Table 3 highlights the effectiveness of cumulative awareness of the three elements of TTK displayed by the leaders as they intervened using the five different strategies for technology adaptation. The total TTK column is calculated by dividing the total possible observations of awareness by the number actually observed by each strategy, all separated by successes and failures. For example, when we look at the three incidents of create strategy success, the total possible observations of TTK would be three incidents multiplied by three elements for a total of nine. We actually observed eight in the data. Thus, the total TTK awareness proportion observed was 89% or 8/9. It is clear in the table that there was higher total awareness in the successful incidents, particularly in the functions and usage and future prediction elements.

If it is necessary to develop and apply understandings of TTK to improve outcomes within ISD efforts, it stands to reason that a similar socio-technical approach would benefit the external efficacy of ISD project designs. That is, ISD projects should be mindful of the state of existing organizational shared technology knowledge and how it relates to the ISD project design and goals. The project can be designed to implement the strategies indicated in this study. The strategies will help indicate the sort of accompanying support and actions that will be necessary for success.

The data indicate extra care needs to be applied when attempting to create or develop new team technology structures. Trying to develop a CT structure (affecting successful technology adaptation) during on-going interaction is apparently not trivial, given that efforts by successful, veteran leaders failed in eight incidents out of the 16 development interventions found. Three successful create strategy incidents all had high levels of TTK awareness (Table 3).

Failure may bring consequences that persist beyond the technology intervention. In one of the failures, incident 19, team members apparently learned that appropriating a new CT during teamwork would not be advisable, a kind of future prediction about likely limitations or incapacities of new CTs. The leader reported that subsequent attempts at technology intervention in this team failed. This indicates the risk that an unsuccessful attempt to create or modify CT structures during teamwork can cause a learning effect such that any attempts at change in the future will be more difficult. This is a substantial risk given the high pressure and tight timelines of the projects studied.

What if a leader neglects to pay attention to technology adaptation needs and existing TTK? Ignoring such needs and knowledge does not preclude adaptation and emergent difficulties. In incident 16 when team members were left to use whatever CT they chose in the absence of the officially sanctioned Object-oriented Modelling and Design (OO) tool, due to the OO tool having been unreliable and unavailable for technical reasons for the first stages of the project. Once the officially selected CT became operational, CT usage habits and beliefs about limitations of the new system had already formed and had to be overcome in order to once again try out the OO tool.

The concept of media stickiness helps explain such an effect. It holds that people become comfortable with the usage structures they develop around individual tools

Table 4 Leader TTK awareness per strategy

	No. of incidents	*Functions and usage*	*Future prediction*	*Usefulness*	*TTK per strategy (%)*
(1) Switch	2	2	2	1	83
(2) Expand	5	5	1	4	67
(3) Merge	2	2	0	0	33
(4) Modify	4	3	0	1	33
(5) Create	10	3	2	10	50

'TTK per strategy' represents the total number of TTK elements observed in the incidents divided by the total number possible to be observed.

Table 5 Rate of strategy success with training

	No. of incidents	*No. of successes*	*Average success rate (%)*	*No. of successes with training*	*Rate of success with training (%)*
(1) Switch	2	2	100	—	0
(2) Expand	5	5	100	1	20
(3) Merge	2	2	100	1	50
(4) Modify	4	2	50	2	100
(5) Create	10	3	30	3	100

and will be increasingly hesitant to change as time passes (Huysman *et al*., 2003). The intervention attempted to get the OO tool used over the media stickiness that had already formed but was unable to 'un-stick' the existing usage patterns. Again the data indicate that ISD team leaders need to actively monitor and manage team CT in relation to interaction productivity.

Greater overall awareness of TTK was associated with less disruptive strategies (Table 4). These strategies (expanding and switching), with one exception, pursued process and temporal coordination goals and were all successful. Four incidents had technical coordination goals, and three of them were failures. Technical coordination involves the management of tasks and their dependencies related to what an ISD team is doing: exchange of information/knowledge on technical details, problems integrating software/hardware components, interfaces, or parts, inconsistent or unreliable releases.

Technical coordination goals appear more difficult to address with technology adaptation interventions due to the inability to get the targeted CT solutions working. Perhaps such solutions tend to be more complex. Two of the three failures involved a substantial failure on the part of the leader in trying to set up and operate OO tools. For such cases, proper design of interaction up front becomes more important. These tools required substantial investments of time and effort to set up and run and could not be added during the project. The one successful technical coordination goal intervention displays leader awareness of functions and usage, unlike the three failures. These findings suggest important future research that may apply the five strategies to understanding how to improve ISD outcomes in organizations. The goals of ISD may be identified in the design of ISD projects, and socio-technical change needs customized to the goals and existing organizational technology knowledge may be applied.

Across the development interventions the data highlight leader awareness of TTK to emphasize the 100% correlation between leader awareness and success *vs* awareness of only usefulness displayed in unsuccessful interventions (Table 2). Perhaps direct emphasis on usefulness contradicts achieving usefulness. This leads us to a proposition for future research:

Leaders aware of the functions and usage TTK available to their teams will be more effective at technology adaptation interventions than leaders aware only of the usefulness TTK.

Second, leaders implementing training along with a development strategy (the three more disruptive strategies: merge, modify, and create) all had successful interventions while none of the failed intervention strategy interventions included training (Table 5). Table 5 highlights the apparent relationship between usage of training and effectiveness of strategies as they become more disruptive. Notice that the rate of success with training increases linearly with increases in disruptiveness of strategies. Admittedly, we have a small sample, but this does point to the strong likelihood of a real, non-random effect at work. Awareness of functions and usage may help leaders recognize the need for training, as all of the successes in the last three strategies displayed such awareness while none of the failures did. It may also guide the design of training to ensure no time is wasted and all necessary topics get covered. In the case of exploitation strategy incidents, training did not appear necessary for success, as only one of the seven successes involved training. Trainings take time and energy.

If they can be avoided, more resources can be spent on the ISD work. Thus, application of the five-strategy model beneficially defines the specific occasions when training is most needed, and future research should explore this proposition:

The more disruptive the chosen strategy for intervention the more that trainings will moderate the success.

The findings reflect on the nature of technology structures as defined in AST. Beyond an overall consensus on how a technology has been appropriated (Salisbury *et al*., 2002), which has proven difficult to isolate and define (Allport & Kerler III, 2003; Chin *et al*., 2003), it has been unclear in existing AST literature exactly what an individual may perceive of the cognitions about technology that a team shares. In the context of distributed, large ISD work, it would be infeasible to approach this problem by having each of the team sub-groups complete survey instruments on their consensus of appropriation for each of the CTs they use, as they are likely to be using at least 12 CTs (Thomas & Bostrom, 2008). Research needs to create new tools to analyze technology adaptation from a socio-technical perspective so that distributed ISD teams may develop necessary technology structures to get their work done. The model developed in this study provides one such needed tool and offers not only insight for studying and training ISD team leaders but also for research and effective design of ISD projects.

Conclusion

This study identifies five strategies for leader interventions targeting technology adaptation ranging from the least structurally disruptive to the most: (1) expand, (2) switch, (3) merge, (4) modify, and (5) create. These strategies derive from an analysis of data from practicing leaders of large-scale, globally distributed ISD projects. The findings include relationships between the five strategies and leader awareness of TTK as a moderator of successful interventions to affect technology adaptation. Implications of these findings include insight into how to study leader interventions in technology adaptation, how to improve globally distributed computer-mediated teamwork, and how to design improved technology adaptation from a socio-technical perspective.

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Appendix

Interview questions

1. Detailed description of what happened. Imagine that you have been placed back in time into that episode. What was the incident and what exactly did you do or say?
2. What were team member-related issues in this incident? [*Probe (as necessary)*: Did the members have to have additional information and communications technologies (ICT) knowledge? Did you sanction or reward any of the members? Did the members' roles within the team change in any way?]
3. What were project task related issues in this incident? [*Probe (as necessary)*: Did you modify any team goals? Did you change or rearrange any of the work process or methodology steps?]
4. How did you use members' ICT knowledge in this incident, if at all?
5. When during the project did this incident happen? [*Note*: Interviewee must give enough answers to at least distinguish between the beginning, mid-project, and end of project.]
6. Effectiveness and evidence of appropriation. Do you consider this an effective or ineffective incident? [Circle One] [*Clarification*: An effective incident is one in which your effort to improve technology use worked.]
7. What evidence do you have of some change in the team's use of technology due to your action(s)? What did you see, hear, or feel? [*Alternates*: How did you know that your intervention was effective/ ineffective? If someone asked you to prove that team technology use changed following your intervention, how would you respond?]
8. Reflection on outcomes. In terms of the project's goal, how did the team's change in technology use result in a different outcome?

Final coding scheme

Team collaboration technology (CT) intervention strategies

1. Exploitation strategies rely on existing team knowledge of a CT based on existing usage within the team.
   - 1.1. Switching from one existing CT to another with identical usage and features due to availability and reliability concerns? — *switch*
   - 1.2. Expanding the usage of an existing CT into another context in which it will be used the same way it has already been used predominantly by people already using it? — *expand*
   - 1.3. Merging two existing CTs with very similar usage and features but different versions used by different sub-groups within a team? — *merge*
2. Development strategies require learning about new CTs and add new CTs or major features.
   - 2.1. Modifying an existing CT to remove or block a category of usage and/or to change the ways the CT is being used? — *modify*
   - 2.2. Creating a new CT capability by adding a new CT? — *create*

Team knowledge awareness

1. Does leader show awareness of team members' understandings of how to operate the CT(s) targeted in the intervention in conveying the incident? — *functions and usage*
2. Does the leader show awareness of team members' understandings of how the CT(s) targeted in the incident may function going forward and potentially break of cause problems? — *future prediction*
3. Does the leader show awareness of the usefulness of the CT(s) targeted in the incident and how they will enable specific work processes or tasks? — *usefulness*

Support actions

1. Did the leader intentionally conduct a training on the CT(s) targeted in the intervention (either virtually, virally (by getting co-workers to train each other), or collocated? — *training*
2. Did the leader set specific policy or rules for the change in usage and explicitly relay them to the team during the incident? — *rule*

Intervention goal

1. Was the leader attempting to expand the team's capability at processing knowledge and sharing it through the intervention? — *knowledge conversion*
2. Was the leader attempting to heal conflict between team members or team sub-groups through the intervention? — *conflict resolution*

Coordination goal (adapted from Espinosa et al., 2007)

1. Was the leader attempting to manage what work was being done (exchange of technical details, reliability or completeness of releases, problems integrating parts, exchange of information on technical details, inconsistent designs) by the team during the intervention? — *technical*
2. Was the leader attempting to manage when work was being done (synchronizing plans and tasks, missed delivery dates, late work from prior phases) by the team during the intervention? — *temporal*
3. Was the leader attempting to manage how work was being done (confusion about phases and procedures to follow, priority confusion and conflicts, duplication or redundant work, frequent project scope changes or lack or clarity, not following agreed protocols or solutions for work processes) by the team during the intervention? — *process*

Intervention result

1. Did the leader report the intervention as a failure, including at least one example of how the team did not begin using the tool and improving how they were working? — *failure*
2. Did the leader report the intervention as a complete or mixed success but the examples given indicate that the team failed to adapt the new CTs as planned and resulting work lead to further complications requiring significant further interventions (such as team collocation) and problems due to the intervention? — *failure*
3. Did the leader report the intervention as a success and the examples given indicate that the team members adapted the changes in CT usage given through the intervention *and* there is evidence that these changes then lead to at least one improvement in the teamwork and resulting project outcomes? — *success*