Understanding Coordination in IT Project-Based Environments: An Examination of Team Cognition and Virtual Team Efficacy

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Abstract
Research has demonstrated how successful coordination can lead to greater organizational performance. In information technology (IT) project-based environments, coordinating the knowledge needed to perform activities is a particularly salient issue. Indeed, research has demonstrated how team cognition, or the awareness team members have about each other's capabilities, is a critical factor for project success. Recently, more advanced technologies have emerged which allow team members to share knowledge effectively in distributed and dynamic environments (e.g. Web 2.0). This study demonstrates how project coordination is a function of both the team cognition each member has as well as their ability to use these technologies in a way that will allow them to harness each others' knowledge. In addition, this relationship is influenced by the nature of the project task environment. A structural model is constructed based on the survey results of 235 project team members to demonstrate the findings.

1. Introduction

The success of information technology (IT) projects has been of genuine concern to organizations for decades [19]. Although methodologies, technologies, and “best practices” have improved over the years, the complexity and dynamics of the development environment have increased as well. The Standish Group reports that over a quarter of the 255 billion dollars spent in 2004 on IS projects was wasted on failure [16] and only 29 percent of all projects were considered successful [17]. Fifty-six percent of projects went over budget and 84 percent of projects went past schedule.

Coordination theory has been one of the primary means for explaining and predicting project success [8, 24, 30]. From this perspective, IS projects are performed best when team members are able to successfully manage project interdependencies [28]. Successfully managing interdependencies depends upon finding the appropriate coordination mechanisms for the task [35]. This study takes a coordination perspective in explaining project success with a focus on understanding the drivers of successful project coordination.

In addition to the coordination perspective, there are several other research streams devoted to understanding and improving project performance with bases in organization theory [25, 30], knowledge management [12, 18, 25], and risk management [32, 38]. However, within much of the research, a common theme is how an individual’s knowledge, and the extent to which his or her knowledge can be successfully shared and coordinated among project team members, leads to overall project success [25].

Referred to as team cognition (also called “transactive memory” or “expertise location”), the knowledge individuals have about the expertise of others has been demonstrated to significantly influence IT project success [12, 18]. However, as IT project team environments become increasingly distributed and dynamic [e.g. 34], it may become more difficult to share and coordinate knowledge among team members even if team cognition is high. For such reasons, Fuller et al. [13] developed the concept of virtual team efficacy (VTE) and demonstrated that the performance of distributed project teams depends, in part, on the knowledge and capabilities that team members have about how to use communication technologies to coordination actions across space and time. Their results showed that VTE did, in fact, influence team effort and communication.

The present study merges these two critical determinants of project success to discover how team cognition combined with VTE influences project coordination and the resulting success. However, rather than investigating their effects directly on project success, we model their impact on the actual project coordination which, from a coordination theory perspective [8, 28], should determine project success. In addition, because the need for collaboration (i.e. “information processing”) is dependent on the characteristics of the task environment [14], the impacts of project uncertainty and interdependence are also modeled. Figure 1 visualizes the theoretical model of the study.
The remainder of the paper is organized as follows. Section 2 reviews the relevant literature on coordination and IT project performance to further outline the variables of interest and to formulate the hypotheses. Section 3 describes the research design and methodology used to test the theoretical model. Section 4 reviews the results of the structural model constructed to analyze the data. Section 5 discusses the implications of the results and limitations and then concludes.

2. Literature Review and Hypotheses

Galbraith [14] refers to two primary mechanisms for managing uncertainty and dependencies: 1) lateral relations, and 2) technology. Essentially, these mechanisms help an organization (or project team) to coordinate effectively. Lateral relations refer to the formal and informal relationships that exist horizontally among organization members. Team cognition is discussed next as a mechanism through which organizations can encourage the formation and use of lateral relations.

2.1. Team Cognition

Team cognition refers to “the mental models collectively held by a group of individuals that enable them to accomplish tasks by acting as a coordinated unit” [18]. Better team cognition helps team members to generate better teamwork predictions [23] and collaboratively adapt their activities [6, 26]. Without adequate team cognition, team members would not be able to share knowledge or coordinate as effectively [39].

Several studies testing team cognition (in terms of the awareness of expertise location) have demonstrated that it has a strong positive relationship to project success [12, 15, 18]. However, from a coordination perspective, it is not the team cognition itself that affects project success, but the influence team cognition has on the ability to coordination successfully which determines project success.

Accordingly, Espinosa et al.’s [11] case study of team cognition and coordination in distributed IS project teams demonstrated that team cognition can reduce the effect that distances have on the ability to coordinate effectively. However, there is little empirical evidence concerning the mediating effect of coordination between team cognition and project success. Therefore, we make the following initial hypothesis:

\[ H1: \text{Team cognition positively influences knowledge coordination.} \]

2.2. Virtual Team Efficacy

Although teams may develop high levels of cognition, the advantages that come from having a strong conceptual map of the knowledge and skills of those you work with may be difficult to come by if the team needs to work in a distributed environment. In this case, teams with greater knowledge and expertise concerning how to use technologies which support greater communication and collaboration will be at an advantage. In essence, Galbraith’s [14] second mechanism for managing uncertainty – technology – may have an interacting effect with lateral relations for managing interdependences and improving project coordination.

Fuller et al. [13] define VTE as “the belief in a team’s ability to use communication technology to coordinate their activities across time and space.” They demonstrated that teams with greater levels of VTE performed better and produced better team results. This finding is supported and motivated by media richness theory [9]. Media richness theory posits that optimal performance is achieved for a group task when the demands for communication richness are met by capabilities of the communication media used to perform the task (e.g. highly uncertain environments required highly rich media) [9, 10]. Face-to-face communication is considered the “richest” form because it occurs in the same time and same place. At the other end of the spectrum, email communication occurs across space and time making it much less rich. Media richness is a contingency theory, meaning that the appropriate degree of media richness depends on the level of task uncertainty. For example, a task with low uncertainty may be completed using simple office software for word processing, spreadsheets, and presentations which are shared and transferred by email. On the other hand, a highly uncertain project may require greater communication capabilities making Google Docs more appropriate because it facilitates real-time, distributed online collaboration. As a result, teams with greater expertise concerning rich technologies will be better able to collaborate and...
work in a distributed environment. In support, Banker et al. [3] discovered that collaborative technologies helped to improve collaboration in product development environments. Therefore, we make the following hypothesis based on media richness theory and prior empirical evidence:

\[ H2: \text{Virtual team efficacy positively influences knowledge coordination.} \]

In addition, as teams increasingly use communication technologies to collaborate, their team cognition should improve as well as the result of their improved communication [13] resulting in the following hypothesis:

\[ H3: \text{Virtual team efficacy positively influences team cognition.} \]

2.3. Coordination and Project Success

There are several studies which demonstrate the impact of coordination on IT project success. Gemino et al. [15] found that effective knowledge coordination leads to reduced project risk and improved project process performance and product performance. Faraj and Sproull [12] demonstrated how knowledge coordination leads to improved individual effectiveness and efficiency in software project teams. Nidumolu [30] demonstrated that horizontal coordination in particular was a significant indicator of project performance. Banker et al. [3] discovered that coordination lead to reduced cycle time and lower development costs. Similarly, Mitchell [29] found that knowledge coordination was a significant indicator of project on-time completion. In summary, the relationship between coordination and project success has been well-established resulting in the final hypothesis:

\[ H4: \text{Knowledge coordination positively influences project outcome quality} \]

2.4 Covariates

The primary covariate in IT project-based environments is the nature of the task environment. According to information processing theory [14], the level of coordination (or “information processing”) required by the project depends on the uncertainty of the task environment. Other variables often associated with project uncertainty project interdependence and complexity, [2, 30, 36, 37, 40]. For this study, two specific measures of the project task environment are used. First, team member interdependence is a variable which is likely to influence team cohesion. As team members are assigned roles which cause them to depend on one another, they are able to develop higher levels of team cohesion. Second project complexity is measured as a function of project difficulty and objectives novelty. For example, newer projects which aren’t as familiar to team members may require greater levels of knowledge coordination to complete.

3. Research Methodology

To test the research model, a cross-sectional survey was administered among the project groups of 235 graduate and undergraduate students enrolled in IS courses in the business school of a large public university in the southwestern United States. The courses included topics on software development, project management, and knowledge management. Each of the classes selected for the survey made use of team projects as a significant portion of the student’s overall grade. The various team projects included tasks such as software development projects, developing reusable learning objects1, and traditional team presentations and reports. Seventy-two percent of the participants were male. Seventy-five percent came from United States origin. The average age was just under 33 years old. The average participant had approximately seven years of professional work experience. Over 75 percent of those with professional work experience currently held jobs in the IT industry.

3.1. Measures

The survey used items based on project perceptions measured in a Likert-style format with responses ranging from 1 (lowest) to 7 (highest). The items measuring project outcome quality [13], knowledge coordination [22], virtual team efficacy [13], team cognition (He et al., 2007), and interdependence [33] were all drawn from prior research with minor modifications for the participant’s particular team project context in some cases. The items measuring objectives novelty and project difficulty were newly created for this survey, but were based on prior literature and findings [36].

Project outcome quality was measured as the quality of the project deliverable and the quality of the process used to accomplish the task. Knowledge coordination was measured as the extent to which decisions, actions, and expectations were coordinated. He et al. [18] identified two facets of team cognition: 1) expertise location, and 2) shared task understanding.

1 Reusable learning objects are web-based interactive “chunks” of independent e-learning modules [27].
This study focuses on the former. In this sense, team cognition is measured as the extent to which each team member understands each other's knowledge and skills and the how well-matched each member's task is to their capabilities. Interdependence is measured as the extent to which each team member's tasks can be performed independently of the others, the extent to which they rely on each other for information, and the extent to which each member is affected by the others. Objectives novelty is measured as the degree to which team members are familiar with performing the type of project they are assigned to and project difficulty is simply a measure of the time and effort which the team member perceived to be required by the project.

Before administration, the survey was reviewed by three project managers, a unit manager, and a vice president from the IT unit of a large utility organization for face validity. Based on their feedback, several items were added, removed, or modified. Next, the study was pilot tested with a group of 20 students. Based on their results, two items were removed. Reliability scores and convergent and discriminant validity tests for the final measurement items are described in the following section.

4. Results

As specified by Anderson and Gerbin’s [1] two-step approach, the measures were first analyzed using confirmatory factor analysis (CFA) and reliability tests to ensure validity. Next, an SEM was constructed to test the hypotheses [4]. Both the measurement and structural models were constructed using LISREL.

4.1. Measurement Model

The CFA model demonstrated adequate fit with a  $\chi^2$ of 163.84 (degrees of freedom [df] = 114), a root mean square error (RMSE) of 0.043, a comparative fit index (CFI) of 0.98, and a non-normed fit index (NNFI) of 0.98 (See Figure 2).

![Figure 2: CFA of model measures](image)

Table 1: Correlations among Variables

<table>
<thead>
<tr>
<th></th>
<th>PQ</th>
<th>KC</th>
<th>VE</th>
<th>TC</th>
<th>IN</th>
<th>ON</th>
<th>PD</th>
</tr>
</thead>
<tbody>
<tr>
<td>PQ</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KC</td>
<td>0.65 (15.9)</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>VE</td>
<td>0.38 (6.48)</td>
<td>0.46 (8.02)</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TC</td>
<td>0.42 (7.13)</td>
<td>0.56 (11.0)</td>
<td>0.36 (5.67)</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IN</td>
<td>0.05 (0.75)</td>
<td>0.04 (0.57)</td>
<td>-0.05 (-0.7)</td>
<td>0.14 (1.90)</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ON</td>
<td>0.35 (5.08)</td>
<td>0.26 (3.53)</td>
<td>0.09 (1.13)</td>
<td>0.24 (3.15)</td>
<td>0.23 (2.95)</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>PD</td>
<td>-0.35 (-5.2)</td>
<td>-0.31 (-4.4)</td>
<td>-0.25 (-3.3)</td>
<td>-0.11 (-1.5)</td>
<td>0.00 (0.01)</td>
<td>-0.16 (-1.9)</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Notes: t-values are in parentheses below correlations; PQ = project quality, KC = knowledge coordination, VE = virtual team efficacy, TC = team cognition, IN = interdependency, ON = objectives novelty, PD = project difficulty

Reliability estimates were above 0.74 for each variable (project quality = 0.98, knowledge coordination = 0.91, virtual team efficacy = 0.91, team cognition = 0.89, interdependence = 0.77, objectives novelty = 0.74, project difficulty = 0.75). Table 1 reports the correlations between variables. All correlations were below 0.5 except for those between...
project quality and knowledge coordination (0.65) and team cognition and knowledge coordination (0.56). In summary, these results suggest acceptable dimensionality, internal consistency and reliability.

4.2. Structural Model

![Figure 3: Structural model with path estimates](image)

Notes: *** p < 0.001; * p < 0.05; $\chi^2 = 192.55$; df = 122; RMSEA = 0.048; CFI = 0.98; NNFI = 0.98

5. Discussion and Concluding Remarks

Based on relevant literature and theory on IT project success, this study investigates how team cognition and virtual team efficacy can impact knowledge coordination and project success. The results demonstrate support for each of the four hypotheses (See Table 2).

Table 2: Summary of Hypotheses and Results

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1: Team cognition positively influences knowledge coordination.</td>
<td>Supported</td>
</tr>
<tr>
<td>H2: Virtual team efficacy positively influences knowledge coordination.</td>
<td>Supported</td>
</tr>
<tr>
<td>H3: Virtual team efficacy positively influences team cognition.</td>
<td>Supported</td>
</tr>
<tr>
<td>H4: Knowledge coordination positively influences project outcome quality.</td>
<td>Supported</td>
</tr>
</tbody>
</table>

As predicted by H1, higher levels of team cognition lead to greater knowledge coordination as indicated by the factor loading in the structural model (0.45, p < 0.001). Similarly, teams that are better at using collaborative technology and fostering virtual team efficacy are also better at coordination their task-relevant knowledge (0.30, p < 0.001) – thus supporting H2. In addition, VTE can also help to improve a team’s cognition (0.37, p < 0.001) as predicted by H3. Finally, H4 was also supported in that greater amounts of project knowledge coordination were significantly positively related to the participants’ perceived project outcome quality.

Interestingly, each of the task environment covariates was significantly related to the variables of interest. Project interdependency was positively related to team cognition (0.16, p < 0.05). In other words, projects which required team members to work with and depend on each other to a greater degree led to higher levels of team cognition. Project difficulty and objectives novelty were also significant negative indicators of project outcome quality (-0.17, p < 0.01 and -0.20, p < 0.01 respectively). As expected, projects requirements which were more difficult and unfamiliar to the team members lead to lower perceived project outcome quality.

Figure 3 visualizes the structural model with a $\chi^2$ of 187.03. As demonstrated, the proposed model fits the data acceptably with a CFI of 0.98, RMSEA of 0.048, non-normed fit index (NNFI) of 0.97 – all acceptable levels for model fit [4].
5.1. Implications and Contributions

Several implications can be drawn from the results of this study for practice and research. For IT professionals working in project environment, this study suggests that technologies designed to support communication and collaboration, i.e., virtual teaming, do have a significant impact on their ability to develop healthy team cognition. This is significant since a variety of so-called “Web 2.0” technologies have emerged with great promise for enhancing the capabilities of distributed individuals wishing to work together [5, 31]. For example, collaborative writing tools such as GroupSystems IT™ which support real-time distributed writing have typically been very expensive for small to medium sized business and have seen only limited use in the past. More recently, a large variety of free and low-cost alternatives have been made available such as Google Docs which support “nearly” real-time distributed support. This research suggests that teams which excel at using such tools can make improvements in their team cognition and knowledge coordination which should, in turn, improve their performance.

For research, this study demonstrates the simultaneous importance of two critical success factors for IT projects – team cognition and VTE. In other words, it’s both “what you know” (team cognition) and “what you know” (VTE) that matters in project success. In addition, while it was already known that team cognition improves project performance (He et al., 2007), this study helps to understand one way in which that cognition develops (i.e., through the use of collaborative technology). In essence, it provides a certain measure of the success of collaborative and communicative technologies.

5.2. Limitations

This study has several limitations which suggest fruitful areas for future research. First, the perceptions measures used in this study may not accurately reflect the objective reality of the variables. For example, knowledge coordination was measured simply as the perceptions which team members have about the efficacy of their knowledge sharing the teamwork relationships. A more accurate measurement would be to capture the actual social network structure through a social network analysis of the team members. This would provide more concrete measures such as the density and centrality of teams and team members [7]. Similarly, objective measures of VTE would strengthen the results of this study. Rather than measuring team members’ perceived capabilities with using communication and collaboration technology, future research should examine actual technology knowledge and usage patterns to understand its influence on team cognition and coordination.

Another limitation is the use of student participants for the survey. While the use of student participants in team-based research is not uncommon [13, 20, 21], students are not necessarily representative of most organization members. Although most of the students were also professional employees working in IT project-based environments, their class projects may not represent typical organization IT projects very well. However, the variables of interest are still very relevant in the student’s class projects. Future research should replicate these findings in actual organization IT project environments.

6. References


