Employing a Cognitive Theory of Collaboration to Guide Team Process and Tool Selection

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Abstract

The value of team work over individual work is the team's ability to amplify the effectiveness of each individual through collective work. Unfortunately, many teams fall short of their potential. Team effectiveness can be obstructed by poor communication, bad decisionmaking, or duplicated efforts among other issues. When this occurs in a military environment the costs of poor team work can be catastrophic. To avoid these failures team leaders, across industries, can choose among software tools, consulting services, black box technology packages or social and behavioral processes to improve team work effectiveness. Regardless of the caliber of the various solutions, selecting among them can be intimidating and provide only marginal benefit if the selected solution is not well suited to the team's problems.

This paper attempts to solve this problem by presenting two approaches to addressing team work effectiveness that are both rooted in a theory of collaboration. This cognitive theory of collaboration, as developed under the Office of Naval Research, provides a structured method for assessing what teams need to know in order to be successful. This structured theory of collaboration, which is drawn from predominant team work and collaboration literature, can then guide team leaders in the selection of a technology-centric or process-centric approach to increased team work effectiveness.

The Need for a Cognitive Theory of Collaboration

Teams are used in all areas from sports to business, academia and the military. Across a range of subjects and goals, a teamwork structure can be implemented in order to leverage individual strengths and to maximize efficiency. According to Network Centric Warfare theory team building is an increasingly important element of success in this Information Age. Vast improvements in communication technology are also making teamwork possible where complex environmental factors would previously have blocked team communication and collaboration.

Despite the growing dependence on teamwork as well as constant improvement in communication technologies, teams can and do still fail. The result of such failures can range from brief annoyances and setbacks to catastrophes that cost people their livelihoods or their lives. To avoid these failures we must first understand the basics reasons that teams fail.

There are three general causes for failures in teamwork. The first is a lack of available resources. In this case, the problem or task as defined for the team is too difficult to accomplish given the available resources. For example if a small community were to try to create a software company with the goal of outpacing Microsoft's revenue within the span of a year, they would fail. Regardless of the resident talent or efforts expended this is simply too large of a task for any community to achieve within one year.

The second cause of failure in teams is a lack of motivation. Many teams have ample resources and a manageable task, yet fail because they are not motivated to put forth the required level of effort to achieve the goal. Whether the lack of motivation is at the managerial level or among junior members of the team it can be enough to delay or even halt a team's progress.

The third cause of failure in teams is a cognitive failure. Teams may have plenty of resources and the motivation to succeed, but if the team does not know what to do they can still fail. Cognitive failures include problems such as misunderstanding the goals, missing a deadline, poor decisionmaking, and the duplication of efforts.

Most bookstores have a wide selection of materials that address the first two causes of team failure listed above. Addressing the third source of failure can be more difficult as there are currently few resources available. This paper will address cognitive sources of team problems, and provide an organized theory of the cognitive issues important for effective team collaboration and process or tool selection.

Defining Teams and Collaboration

The three causes of team failure defined above apply to all kinds of teams. Action teams such as sports or military teams, and thinking teams that commonly occur in businesses can all experience problems due to a lack of resources, motivation or team knowledge. The cognitive theory presented below also applies to these various team types. Eduardo Salas' definition of a team can be used here as a benchmark for our discussion of a team:

> "a distinguishable set of two or more people who interact, dynamically, interdependently, and adaptively toward a common and valued goal/objective/mission, who have each been assigned specific roles or functions to perform and who have a limited life-space of members" (Salas et al., 1992 as quoted in Mathieu, 2000)

A benefit of collaboration for both thinking teams and action teams is the ability to leverage each teammate's work leading to increased productivity, increased quality, or both increased productivity and quality. Thinking teams can leverage each other's thoughts and knowledge by dividing task work according to team member personal strengths, or by working together to create better products. Action teams can leverage each other's physical actions in order to cover more territory, work different shifts and create task specialists based on skill, strength or experience.

While there are obvious benefits to teams and collaboration there are many factors that can make collaboration more difficult. Teams that are geographically or spatially distributed can have a difficult time sharing information and maintaining a current situation assessment. Teams that are constantly adding or losing team members, changing roles or structure can find it difficult to know who is responsible for what task or information. Klein Associates, a subcontractor under Evidence Based Research, Inc. (EBR) for this Small Business Innovative Research (SBIR), developed the following taxonomy of teams which articulates some of these dimensions and the affected knowledge areas.

Team Dimension	Dimension Subcategories
Distribution	• Physical—spatial separation of team members • Temporal—e.g., working different shifts • Expertise—spatial and temporal distribution of experts and expertise • Information—spatial distribution of information
Roles and Functions	• Stability of definition—whether roles are clearly defined or become defined in process of performing work • Experience--extent that each team member is experienced with assigned roles and collaboration tools • Familiarity—extent each team member is familiar with roles and functions of other team members • Team member expertise—extent that individual team members have specialized expertise needed for their assigned tasks
Team Structure	• Hierarchical vs. flat—extent that team has designated leader in charge or is peer-to-peer • Size—number of members • Permanent vs. ad hoc—extent it works together over extended period of time, or is brought together for one task • Single vs. team-of-teams—extent that teams can be decomposed into collaborating sub-teams • Turn-over—stability of team membership
Team member dependencies	• Independence—extent that each team member depends on other team members to perform his task • Interaction frequency--how often team members must interact • Synchronization—requirement for and schedule tolerance of temporal sequencing of tasks performed by different members • Cognitive—extent that team members must pay attention to each others' tasks • Task sharing—extent to which each team member has own task or all team members share the same tasks • Processing flow-- individual/parallel or sequential

Team Dimension	Dimension Subcategories
Decision Making	• Group makes decision vs. leader makes decision • Reactive vs. proactive—extent that tasks require team to react to uncontrollable events • Degree of time pressure • Stakes--degree of risk and responsibility

Table 1. Taxonomy of Collaboration Teams

The dimensions listed in the first column are the areas that can become more difficult to perform successfully depending on the state of the dimension subcategory listed in the second column. While none of these states or dimensions renders effective collaboration impossible, it can make collaboration more difficult since it requires more knowledge to be effectively held and shared by the team. For example, a team that uses split shifts in order to have a team working around the clock will have to work harder at making sure task status information gets passed on from shift to shift. A team with shifting team members will have the additional challenge of assigning task work in a way that work will not be lost if team members are shifted to another task or team.

This taxonomy begins to answer the question of what teams need to know in order to collaborate effectively. The following section will address what knowledge teams need and begin to lay the groundwork of the cognitive theory for collaboration developed by EBR under the Office of Naval Research SBIR.

What Teams Need to Know

The following statements identify four basic principles of knowledge and its role in teams to facilitate effective teamwork.

1. Knowledge is central to collaboration and teamwork. Teams whose members know what they need to know can work together effectively. Those that do not are prone to various kinds of predictable errors, with the type of error dependent on the type of knowledge deficiency (Liang, 1995)

2. Knowledge must be distributed among members of a team. Everybody does not need to know everything for a team to be effective. But every team member does need to know how to get the knowledge he or she needs. (Wegner, 1987)

3. Individuals need to know about both "taskwork" and teamwork. Taskwork knowledge is what team members need to carry out their tasks alone. Teamwork knowledge is what team members need to know to work together effectively (Canon-Bowers, 1993)

4. The collaborative dialog helps generate the needed teamwork and taskwork knowledge. Team members exchange ideas to put in place the knowledge and

understandings that team members must have for the team to achieve its mission. (Argote, 2000)

The first statement is the foundation of this cognitive approach to effective team collaboration. It establishes that there are certain knowledge areas that teams need to have, and without them they are likely to experience associated problems. The second statement on knowledge qualifies the first, by indicating that while certain knowledge is required, the same knowledge is not required equally by each team member. What is more important is that all knowledge is at least accessible by each team member. The third statement divides knowledge into two preliminary categories. One knowledge category relates to an individual person's task while the other category relates to each team member's interactions with the rest of the team. The last statement adds that both categories of knowledge can be created, facilitated and exchanged through effective communication.

While these statements establish some important tenets to team work, they do not go very far to aid teams in diagnosing or fixing any problems the team might have. Dr. David Noble of Evidence Based Research, through a Small Business Innovative Research grant from the Office of Naval Research has organized a set of 12 knowledge categories that, when in place, aid a team's collaboration and improve its effectiveness. Since these categories of knowledge enable effective collaboration, they will heretofore be referred to as the knowledge enablers, or simply the enablers. These twelve enablers have been broken down into a series of sub-enablers with associated risks and symptoms that can be used to diagnose cognitive failures in a team. The next section will describe these twelve knowledge enablers, their sub-enablers and the interdependent relationship of these enablers.

The Twelve Knowledge Enablers

The twelve knowledge enablers described below can be broken into two groups. The first six enablers assess relatively static knowledge of the team in the preparation stage. The last six enablers assess task, team and situation knowledge in real time. These enablers are designed to aid teams to do two things: 1) understand what individual and team, taskwork and teamwork knowledge is important to effective collaboration, and 2) help the team to put the knowledge in place by educating the team on observable symptoms and risks that can make the knowledge harder to get, and to recognize when knowledge gaps and deficiencies occur.

The enablers and sub-enablers follow:

1. **Goal understanding**. Knowing what the customer wants.
   a. *What client wants*
   b. *Criteria for evaluating team product*

2. **Understanding of roles, tasks, and schedule**. Knowing who's supposed to do what and when, and with what information and resources.

a. Tasks
b. Roles and role backups
c. Schedule
d. Assigned resources/specified information needs
e. Assumptions and contingencies
f. Criteria for evaluating task progress

3. **Understanding of relationships and dependencies**. Knowing how entities, events, and tasks impact the plan.

a. Task to task
b. Task to goal
c. Situation to plan
d. Resource/information/labor to tasks

4. **Understanding others.** Knowing what other team members' backgrounds, capabilities, and preferences are.

a. Others capabilities/knowledge
b. Others values/preferences
c. Others work habits
d. Others motives/rationale for working on project

5. **Understanding of team "business rules."** Having and knowing effective and agreed upon rules for team members interacting with each other.

a. Team etiquette
b. Team policies, like how to resolve conflicts

6. **Task skills**. Knowing how to do one's assigned work.

a. Mechanics of performing tasks
b. Using support tools
c. Finding needed information
d. Getting help

7. **Activity awareness**. Knowing what others are doing now and current need for doing it.

a. What others are doing
b. Their level of engagement and busyness
c. Whether it's work that the team member should be doing (including for self)

8. **Understanding of the external situation**. Knowing status of people (including client), things, and events of the world outside of the team and projecting future changes.

a. What's happening
b. What's significant to team and why
c. Projecting future events

9. **Current task assessment**. Keeping tasks on track, knowing how well own and other's tasks are progressing, and when to offer help.

a. Task status: who's on it,work, resources and information status
b. Signs of problems, and if task is on track
c. Task needs: advice, information, resources, labor

10. **Mutual understanding**. Knowing what other team members understand now and knowing if they agree or disagree.

a. Transfer of meaning--how others understand input
b. Where others agree or disagree and why

11. **Plan assessment**. Predicting whether the plan will still enable the team to achieve its goals.
Knowing:

a. Inter-task projections: resources, people, information availability
b. Plan prospects and danger points

12. **Understanding of decision drivers**. Judging and applying the criteria for selecting an action.
Knowing:

a. the right factors to consider
b. deadline for decision needs to be made
c. how to manage uncertainty
d. right people to involve

These enablers and sub-enablers define the knowledge areas relevant to both teamwork and taskwork for thinking or action teams. They are not designed to assess the quality of a team's plan, goal or decision making procedures, but rather are intended to aid team leaders and members in determining whether the team has knowledge of what the plan, goal and decision making procedures are. The enablers define the knowledge areas team members need to have and share in order to effectively handle their own tasks, facilitate both peer and team tasks, and to collectively meet established deadlines with products deemed successful by both team and customer standards.

These knowledge enablers are not independent from one another. In order for a team to accurately assess their likelihood of meeting team goals given the current task and

situation status if they continue with the plan in place [enabler 11], the team must also have knowledge in place about what the original plan was [enabler 2], what the customer and team goals were [enabler 1] and what the current task and situation status are [enablers 9 and 8]. For another example, diagnosing team members' task skills [enabler 6] may be intertwined with assessing the teams' understanding of other team members [enabler 4] as well as knowing and having effective business rules [enabler 5]. What may appear to be a team member who does not effectively utilize the expert knowledge of a peer [enabler 6] could either be a team member who does not know that the team has a resident expert on the subject [enabler 4], or does not believe that team policies allow for the information exchange [enabler 5]. Due to this interdependency of the knowledge enablers, accurately attributing observed symptoms of knowledge deficiencies to their causal knowledge deficiency can be difficult. EBR has developed a couple of methods that exploit this cognitive theory of collaboration to help teams diagnose and fix their problems. These methods are presented in the following section.

Employing a Cognitive Theory of Collaboration

In order to have an accurate diagnosis of a team it is important to involve both team leaders and team members in the process. As the second statement of team knowledge indicated it is crucial that all team members have the knowledge they require, or at least a means of obtaining required knowledge. A survey, discussion or observation that involves only part of a team will measure the cognition of only a subset of the team and will lead to an incomplete assessment. Including the full team in the diagnosis will allow for the full range of perspectives and the presence of any disagreements to be represented.

This cognitive theory can be exploited to conduct an assessment of team cognition using one of several methods. Dr. Noble and John Kirzl have written about using these 12 knowledge enablers along with 9 critical observable behaviors for an objective evaluation of team collaboration (Noble, Kirzl, 2003). EBR has also developed an expert system based on this cognitive theory that helps teams diagnose and fix knowledge-related collaboration problems. This tool, the Collaboration Advizor, asks teams a variety of questions that probe for the presence of symptoms, risks, and factors that make it harder for the team to obtain and share needed knowledge. Using questions that have been derived directly from one or more of the enablers the tool is able to diagnose specific knowledge problem areas for both individuals and the team as a whole. The selection and presentation of questions, symptoms, risks and the resulting diagnosis serves to both educate teams of the knowledge categories important for effective team collaboration, and to help them recognize current knowledge deficiencies as well as learn symptoms and risks to watch for in diagnosing future teams and knowledge deficiencies. The Advizor also provides recommendations based on the individual enablers or an intertwined set of enablers that are the source of a team's problems.

Addressing Cognitive Problems within a Team

Regardless of the method used to diagnose team knowledge strength, these enablers are also useful in guiding teams to an appropriate solution to knowledge weaknesses identified by a tailored team diagnosis. Once a full team diagnosis has been administered, it is then possible for the team to select the appropriate remedy based on the problem area or areas. The value of first conducting a diagnosis of the team is to adequately inform the team of areas that need improving and knowledge that has not yet been effectively established or shared.

As mentioned in the introductory paragraphs, teams can select among software packages, expert consultant services, printed literature, technology intensive constructions or basic social and behavioral policies to help establish and share knowledge in the team's deficient areas. These solutions have many options and they can range from technology-intensive team work spaces incorporating software designed to aid in document sharing, task management, planning, and asynchronous communication, to a meeting room with a chalkboard where team members can meet and post results for the same activities. A list of solutions to various teamwork problems could be drawn up with at least one technology-centric and one social process-centric approach for each problem area. The important lesson is that no solution should be magical, able to mystically cure a team with reported problems. This is because all potentially effective solutions are attempting to fix one or more of the deficient knowledge areas. By first employing the cognitive theory of collaboration to determine the current cognitive status of a select team, the team then has a set of metrics to employ when selecting a technological or social/behavioral solution. Rather than searching for general 'team-ware' or 'group-ware' products, teams can evaluate products based on the specific issue they claim to address. This will help to ensure that attempted solutions will benefit the team by addressing the areas of concern and not merely re-fortify or tamper with already successful team efforts.

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