A Theoretical Framework for a Dynamic Team Learning and Adaptation System

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***Abstract*— This paper will discuss a model for team learning and adaptation by applying sociotechnical and cognitive systems concepts to a model previously developed by [1] to facilitate double-loop learning in teams and organizations. Organizational knowledge assets will be explained relative to team learning followed by an explanation of the sociotechnical system that the model is based upon. An overview of the team cognitive systems model will be provided as a precursor to explaining the learning and adaptation system. The team learning and adaptation model combines sociotechnical and cognitive systems elements to provide a model explaining how team learning at the tactical level can be aligned with other organizational resources while aligning these efforts towards organizational strategy. The proposed model also provides a holistic means for implementing a problem-solving methodology within the sociotechnical and cognitive systems contexts.**

The aim of this paper is to aid practitioners seeking to improve how his or her team learns, collaborates, and innovates at all levels of the organization. The paper is geared mainly towards practitioners interested in improving his or her team's performance. Academics interested in team learning and knowledge sharing may also find the model of interest in academic pursuits related to team learning and adaptation. Practitioners can use this model to identify shortcomings in team learning and adaptation performance relative to specific work requirements. Academicians can use the model to explain sociotechnical and environmental interactions relative to how teams perform learning and adapting behaviors.

***Index Terms*—Team learning, team adaptation, team creativity, team cognition, organizational learning.**

I. Introduction

Problem solving scenarios provide organizations with a unique opportunity to evolve and improve existing technologies, competencies, and capabilities towards constantly changing environmental conditions. These opportunities are rarely capitalized as traditional organizational structures and the methods used for capturing and sharing knowledge are ill-equipped at applying organizational resources towards value-centered knowledge creation. This failure is compounded at the team level as individuals operating within a peculiar environmental context (such as virtual teams) can face difficulties in learning from others, identifying those with valuable knowledge, and sharing lessons learned with others within the organization. The ability of teams to adapt organizational resources to address social and technical challenges is also jeopardized due to the inability of knowledge sharing and coordination systems to reach entities beyond those directly influenced by the problem [1].

The purpose of the learning and adaptation model proposed in this paper is to increase team learning efficiency by aligning team member learning with organizational knowledge assets. The model provides value to teams and organizations in several ways. The model provides value by providing a methodology for improving a team's ability to learn from problem solving through a particular team design [3]. This value is based on the assumption that traditional team designs assume that all team members have access to adequate resources, team members openly communicate with each other. and that knowledge can be easily captured and stored [2]. The assumption that knowledge is a tangible asset ignores the fact that most knowledge is tacit and context-specific and therefore cannot be captured [2]. The peculiar social and technical context of teams (i.e. virtual teams) can also differ significantly from that of previous team models [7]. Differences in team behavior and performance can also cause dysfunctions that elude traditional learning methods and tools such as team transactive memory (allowing team members to identify individuals proficient in solving particular problems) or high-context information sharing between distant team members.

The learning and adaptation model also reduces confusion while designing a team learning and adaptation system strategy. The amount and complexity of knowledge and information generated grows exponentially as one moves upwards throughout the organization [3]. This growth in amount and complexity of knowledge and information is especially true of virtual teams that function within and apply organizational resources within a peculiar and distinct context. Information complexity also creates additional problems when traditional knowledge sharing systems aim to standardize processes and technologies. The ability of knowledge sharing systems to absorb complexity resident in a particular context is reduced by standardization processes and technologies by removing context-specific solutions. Knowledge and information within a certain context which is valuable in creating a competitive advantage is either lost or isolated to team boundaries and not shared outside the immediate team [2]. A model such as the one proposed in this paper can

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provide the manager or decision-maker with a framework to facilitate more flexible team sharing between teams.

Organizations benefit from a comprehensive learning and adaptation model by increasing the number and variety of technologies available to internal entities. An increased variety of technologies subsequently allows each element to function more effectively by providing more effective means to evolve organizational technologies towards a particular context. Management functions within the organization can use this model to align internal functions towards more effective cross-functional knowledge sharing. An increase in organizational knowledge also provides the means for these functions to absorb team knowledge variety. Organizational strategies can then be improved as improved technologies make customer-specific knowledge available at the tactical level to evolve organizational competencies and capabilities at the strategic level [3]. An organization can therefore develop and evolve a competitive advantage by taking advantage of the distinct competencies, capabilities, and technologies that virtual team knowledge can provide.

Arguably the most valuable function of a learning and adaptation system is to increase team creativity by developing new thought patterns based on interactions with more diverse knowledge sources. A learning and adaptation system stimulates team creativity by exposing individuals to new ideas and experiences while empowering them to apply these ideas and experiences to future problems. Team learning subsequently improves as diverse ideas and experiences create additional context-specific knowledge which can be applied to future problems.

II. Organizational Knowledge Assets: Technologies, Competencies, and Capabilities

The ability of organizations to learn from and adapt from its environment is useful for evolving organizational technologies towards specific environmental factors. Organizational competencies improve as technologies evolve towards specific environmental factors which subsequently enables the organization to develop and adapt internal strategic capabilities to address these changing environmental conditions. Capabilities, which benefit from the application of contextual factors learned through team interactions with the surrounding environment, can then provide a competitive advantage over other organizations competing within the same environment. These competitive advantages provide the means for an organization to adapt more quickly at the strategic level, especially in environments with high levels of variability [3].

Boisot [3] defines three organizational knowledge assets found within various levels of the organization. Technology is defined within a sociotechnical context similar to that posed by [3] as the interaction of social and technical systems aimed towards performing certain tasks that provide value to the organization and environment. These technologies are present in processes, procedures, and tangible assets designed for a specific purpose. A group of technologies form a competency which is designed to achieve a certain level of performance by enabling the technologies towards specific outcomes. Capabilities form the strategic layer of knowledge assets, defined by [3] as groups of competencies strategically arranged to enable a certain application or integration of technologies. These knowledge assets are inter-related such that the effectiveness of an organization's competencies relies on the ability of its developed technologies to address organizational needs at the tactical level and an organization's capabilities are reliant on the ability of its competencies to enable organizational assets towards organizational strategies. An organization's competitive strategy, defined as unique strategies, competencies, and capabilities unique to the organization which provides a distinct advantage in the marketplace, relies heavily on the ability of the organization to design and evolve new and existing organizational knowledge assets towards unique opportunities.

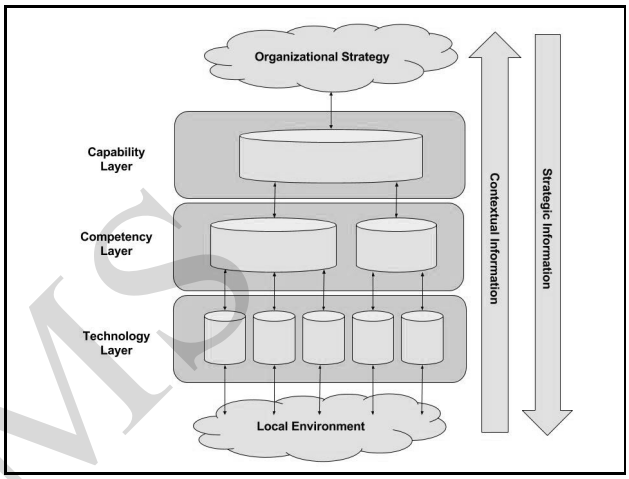


Fig.1 Relationship between technologies, competencies, and capabilities

The application of technologies, capabilities, and competencies is an important part of team and organizational learning and adaptation as it provides a means for learning and adaptation to occur throughout an organization. The learning and adaptation of organizational elements based on learning at the team level can be fostered by applying tactical-level environmental factors to develop more robust organizational capabilities and competencies. Organizational elements can subsequently align team actions to strategies by evolving the technologies use at the team level to address organizational priorities. This relationship serves as a closed-loop feedback mechanism where those adding value at the local level are able to communicate any changes in the local environment to organizational functions while the organizational management function provides feedback to the team to align team interactions at the local environment with organizational strategy. The learning and adaptation model is *recursive* such that the functions and structure of the model can be applied to higher level systems within the organization. The application of a recursive model within a social system is outside of the scope of this paper; please refer to publications such as *Diagnosing the System for Organizations* (Beer, 1995) for further details.

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III. THE SOCIOTECHNICAL MODEL

The learning and adaptation model uses a cognitive systems model composed of social, psychological, and technical subsystems [9]. The concept of cognitive systems refers to how individuals cope with complexity in his or her immediate environment using technology to perform cognitive actions (Patterson & Stephens in [5]). These cognitive actions provide the psychological aspect of a cognitive system by interacting with the social and technical subsystems to address environmental complexity factors. The psychological aspect of the sociotechnical system is limited by the work domain such that the work domain defines which specific environmental, social, and technical elements that organizational assets are aligned towards.

The general premise of a sociotechnical systems approach is that social and technical subsystems (represented by the work domain and activity domain in the team cognitive systems model) are *separate but interdependent* subsystems that must be *jointly* optimized by considering how both can work together to address environmental factors [4]. Cognitive systems engineering works within a sociotechnical systems approach to define work elements which subsequently define work domain elements requiring attention [4].

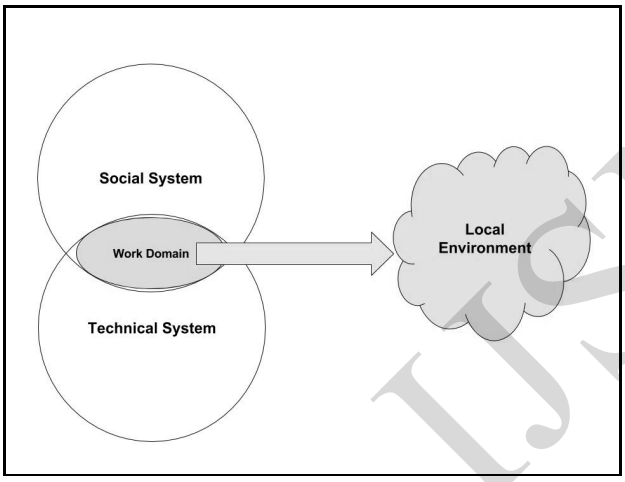


Fig. 2: Sociotechnical interactions with the environment

The capability of a team to address environmental factors are defined based on social and technical subsystem interdependencies and the level of coordination between them. Organizational learning and adaptation efforts must therefore not only consider social (activity domain) and technical (work domain) subsystem capabilities but how effectively the interactions between the two subsystems can address work domain requirements and how these interactions align with organizational strategy. This alignment with organizational strategy is addressed within the context of the team cognitive systems model through changes in an organization's competencies (which define the overall strategy), capabilities (which define how the organization allocates resources towards strategic priorities), and technologies (the tools, processes, and procedures used to execute organizational strategy at the team level).

The social subsystem comprises individuals assigned to a particular role in support of team goals and objectives. Team members can have separate roles and responsibilities but must be aligned such that his or her interactions aid other team members towards these goals and objectives. This alignment of team member actions towards team goals and objectives is complicated by the fact that individuals within a social system can have goals different from those of the team and other team members. The technical subsystem is composed of work elements the team uses within the cognitive model to define the work domain (defined as the portion of the sociotechnical system being controlled independent of any individual worker, automation, event task, goal, or interface [9]). The inclusion of a work domain in the sociotechnical systems model is important as it illustrates key social and technical system interdependencies and how these interactions utilize work elements to accomplish team goals.

The basic concept of this model as it applies to team learning and adaptation begins with the interactions between the work and activity domains. The *work domain* refers to specific physical elements, tasks, processes, and procedures a team uses to perform tasks that provide value to the environment and organization. It is important to note that the capability of the work domain to provide value is directly limited by the social and technical systems. These limitations are especially true within the context of organizational strategy as both are manipulated by the organization to control which actions are available to the team.

The design of these subsystems is crucial to team performance as it defines how actors within the system produce *sensible* and *competent* actions which subsequently define how the team accomplishes its goals (Koschmann, Dunnington, & Kim in [5]). Note that the alignment of organizational strategy to team capability (not to be confused with the organizational capability) and subsequently its ability to interact with the local environment occurs as part of a closed-feedback loop described in the previous section on technologies, capabilities, and competencies.

IV. THE TEAM COGNITIVE SYSTEMS MODEL

A cognitive systems approach is valuable to team learning as it provides a means to systemically maximizing cognitive tasks across all team tasks, especially when team tasks are distributed fairly and evenly across team members (Patterson & Stephens in [5]). The concept of cognitive systems states that interdependency across work elements is necessary in complex sociotechnical domains (Patterson & Stephens in [5]). The cognitive subsystem links the various sociotechnical elements towards the goals of the system which subsequently are aligned towards organizational objectives. Interdependency across work elements is especially important in environments where no one team member could physically perform all operations needed at one time (Patterson & Stephens in [5]). Complex environments also benefit from high interdependency between team members to perform distinct roles at differing levels of

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expertise and capability and at different stages in a team's processes.

The team cognitive system has five macrocognition functions providing a team with the ability to *self-organize* its capabilities by aligning team and individual problem-solving efforts with environmental factors. This alignment of team and individual tasks with its environment enables the team to detect unexpected or undesired changes in the work domain, understand the reasons for the change, identify possible means to mitigate or eliminate the problem, and coordinate resources towards the problem-solving efforts. *Detecting* allows a team to notice when events take and unexpected positive or negative direction (Patterson & Stephens in [5]). Note that this function only provides the means to detect an unexpected change and not the reason for the change.

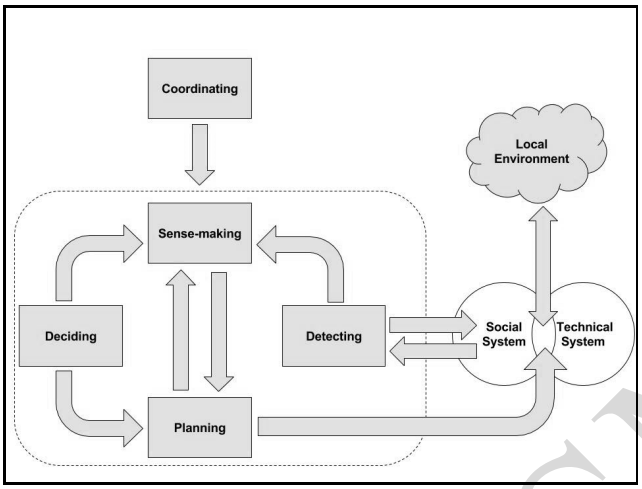


Fig. 3: Team cognitive systems model

Sense-making provides for the collecting, corroborating, and assembly of information related to the detected change (Patterson & Stephens in [5]). The main purpose of this function is simply to explain the factors surrounding the unexpected change. The *planning* function adaptively responds to environmental changes by adapting sociotechnical system elements in response to the unexpected change. Examples of the planning function within the context of problem solving would be to identify a means to return the change to the 'desired state' (mitigation) or redesigning work domain elements to provide a more desirable future state (changing the design to eliminate or reduce future incidences of the problem). The *deciding* function sorts through all possible hypotheses to commit resources to one or more courses of action (Patterson & Stephens in [5]).

Coordinating refers to the ability to manage activity and communication interdependencies across individuals within the team acting in roles aligned towards team goals (Patterson & Stephens in [5]). The coordinating function is especially important in team problem solving as it enables teams to pull and align resources that otherwise may not be known by the individual team members. This function provides as a resource management function linked with other levels of the organization to provide oversight of and feedback from sociotechnical elements to align these elements with organizational strategy and make resources available as required. Note that within the context of team learning the coordination function also makes learning from teams available to other teams and entities within the organization who may benefit from the learning.

A key element of the cognitive systems approach is the concept of the work domain. The work domain is defined within the context of the sociotechnical systems model as the interaction of social and technical work elements and the environmental elements these interactions manipulate [9]. The work domain within the context of learning and adaptation is defined by the environmental factors that the social and technical subsystems within the sociotechnical system are designed to interact with. These work elements are further limited by the capabilities of the social and technical subsystems and the possible interactions between the two subsystems. It is through the organizational allocation of resources as they relate to organizational strategic priorities and the ability of the social subsystem to interact with its technical counterparts that the work domain is shaped by organizational design elements. In fact, it is possible for organizational resources to be allocated to either subsystem while at the same time the social subsystem is unable to effectively utilize these additional resources resulting in a *sub-optimization* of the two subsystems due to resulting inefficient interactions between the existing system and the new resources.

V. The Cognitive Learning and Adaptation Model

Team learning within cognitive systems begins as employees interact with their immediate environment through the work domain. Learning at the *front-line* level is mostly tactical in nature and involves social and technical interactions which influence how technology (within the context of this paper) is designed and used. An example would be an employee modifying a particular technology to meet immediate customer needs but which was not originally designed. *Mid-level* organizational learning is aimed mainly towards aligning technologies toward specific competencies which in turn may affect multiple technologies.

Optimizing a particular set of technologies to satisfy a particular customer need would be an example of aligning technologies to create a capability. A capability would involve the aligning of competencies (and the technologies that compose them) into a strategic skill; an example would be aligning competencies to apply them in a new market opportunity. Technology integration involves physical assets and processes whereas at the top level these assets are aligned using various concepts, interpretations, and preferences (such as budgeting and forecasting) to integrate various competencies into an organizational capability.

The type of learning used to improve each type of knowledge asset differs depending on the type of asset being improved. For example, assume that front-line employees identify the need to modify a piece of machinery to perform a specialized local task. The team (part of the social subsystem)

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learns about the deficiency of the piece of machinery (part of the technical subsystem) through feedback from its interactions with the work domain. This learning can then be shared with others using social (direct interactions with other team members, 'water cooler' chats) and technical (telephone, email, databases) methods. The mid-level (operational) employees are alerted of the deficiency and the need to alter the machinery and, after management review and approval, revises organizational policies and procedures and allocate organizational resources to support this new capability. Employees at the strategic level (i.e. senior management) decide if this new technological capability should be exploited by controlling resources available at the lower levels. These strategic efforts subsequently serve to encourage or discourage future learning application to organizational assets as a form of organizational strategic policy.

Team learning plays a part in team adaptation such that the ability of a team to adapt work elements to environmental changes relies heavily on previous learning to provide the knowledge necessary to develop effective solutions. Team adaptation occurs when the team (or an individual within the team) recognizes that a change has occurred within the immediate environment and is allowed to address the unexpected situation [6]. Teams attempting to apply the learning to their particular context require a shared context about the temporal and contextual elements of the learning to understand how learning from other teams or team members apply to their own specific context [6]. Coordination between teams and team members within the context of learning is critical as it allows for these entities to acquire information, combine it with prior learning and information, and share the resultant knowledge with others. The learning and adaptation model therefore focuses on coordination as an important factor in effective team learning and adaptation.

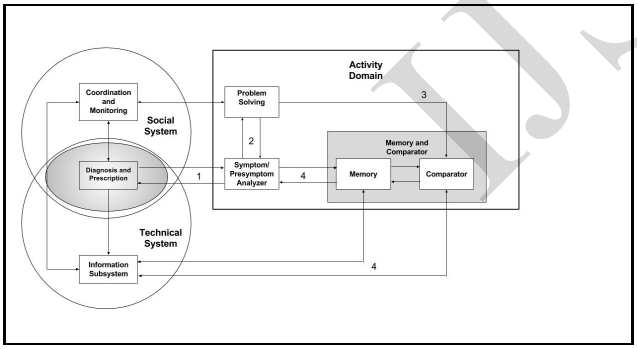


Fig. 4. The cognitive learning and adaptation model

The model has two distinct and interdependent parts. The *sociotechnical* system, defined in figure 4 as the social and technical systems and the shaded work domain, interacts with the environment and provides the opportunity for team members to learn from the environment. The *activity domain* identified in figure 4 provides the activities used by the team to identify a problem, mobilize resources to resolve the problem, solve the problem, and share the lessons gleaned from the learning to others (note that some cognitive systems engineering references refer to the activity domain as a part of the work domain itself; the activity domain was separated from the work domain as a means to simplify the model). These lessons are then used to improve the ability of the team (or other elements within the organization) to resolve future problems more effectively and *adapt* work elements to better interact with the environment in a manner that is aligned with organizational strategy.

Learning and adaptation begins with deviations from expected performance in the work domain detected by the *diagnosis* portion of *diagnosis and prescription* function within the work domain. Information from the *diagnosis and prescription* function is sent to the *symptom/presymptom* analyzer (1). The purpose of the *symptom/presymptom* analyzer is to define problem symptoms by applying predefined work domain variables (presymptoms) to changes detected by the *diagnosis and prescription* function. This information is either captured by team members on a *decision record* (also referred to as after-action reports (AAR) or lessons learned worksheets) or by automated means. An example of a presymptom would be a temperature outside of expected limits; the presymptom function would provide such information to the symptom function such as where the temperature resides within a prescribed normal range and system elements related to the temperature indication. The symptom portion of the *presymptom/symptom analyzer* would then apply tools such as statistical controls to define trends related to the abnormal temperature to determine if the presymptom requires further attention.

Information from the *symptom/presymptom* analyzer is provided to the *problem-solving* function to identify work domain variables responsible for the deviation detected in the *diagnosis and prescription* function (2). The *problem solving* function will refer to the *symptom/presymptom* analyzer to request additional information as required to make an effective decision (the *symptom/presymptom* analyzer will refer to the *diagnosis and prescription* function to improve understanding of the symptoms provided to the *problem solving* function if insufficient information is available). The activity domain, defined within the context of this system as the activities performed by team members to perform work-related tasks, interacts with the work domain through a *symptom/presymptom analysis* function to monitor and detect unexpected or undesirable changes in the work domain.

The *problem solving* function compares information defined during problem solving to previous symptoms and solutions stored in the *memory and comparator* function to determine if previous solutions could be used (3). The *comparator* sub-function refers to the *information subsystem* within the technical system if a problem with symptoms similar to the one identified by the *symptom/presymptom* analyzer was previously resolved. The *memory* portion of the *memory and comparator* function captures information related to the problem and provides it to the *comparator* function to compare observed symptoms to those stored in the *information* subsystem (4). All of the information gathered by the *memory*

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and comparator functions are stored in the *information* subsystem in the form that is easily retrievable by others.

The function of the *information* subsystem is two-fold; to provide a means for storing information created during problem solving and to make the information easily retrievable. Information should be stored as close to the original source as possible so that the loss of valuable context is minimized. The stored information should also be easy to retrieve in order to reduce frustration and time related to identifying and defining needed information.

The *coordination and monitoring* function monitors the work domain through the *diagnosis and prescription* function, aligns resources aimed towards solving the problem as needed, and coordinates the sharing of knowledge to other team members and organizational functions. The coordination portion of this function aligns the *information* subsystem to ensure that all team members have adequate information and access to solve the problem and share subsequent knowledge gained throughout the team and other organizational functions. This function also pulls resources when needed as required by the individual or team to resolve the problem. Arguably the most important function of the *coordination and monitoring* function is to facilitate effective communication between all involved parties using an integrated communication strategy which links team problem-solving efforts with organizational resources and organizational strategy.

VI. Recommendations

Applying the model to an existing sociotechnical system provides a manager with the means to both understand how the current system performs and identify any inadequacies in the current design. Improvements to an existing system can be made once the current system is modeled and the needs of the current system in relation to team learning and adaptation can be identified. One must avoid applying any solutions to systemic deficiencies without first understanding the needs of the sociotechnical system and how any proposed changes will affect the social and technical subsystems. This is critical as any effects on the social and technical subsystems will subsequently influence the effectiveness of both subsystems to interact with the work domain.

VII. Conclusion

Organizations find it difficult to exploit team learning for a variety of reasons. A primary reason for this lack of knowledge sharing is that distance (both physical and social) imposed on team relationships present barriers for traditional and formalized knowledge sharing to occur [8]. Team members either lack the ability (physical) or desire (social) to share with other teams, especially within a virtual context. This barrier to organizational knowledge sharing is compounded by traditional siloed organizational structures encouraging knowledge sharing vertically within his or her "silo" rather than horizontally [8]. An unintended consequence of this lack of integration is that entities outside of the immediate team that may benefit from this knowledge are unaware of the knowledge. The same lessons are learned multiple times as each team becomes a sole repository hesitant to sharing knowledge with others [8]

The model defines certain elements responsible for both encouraging the opportunities for learning and implementing methods to make this knowledge available to others. Note that this paper does not propose specific methods and tools for each element but rather allows managers to understand which functions require further attention. Future research may address and identify solutions for managers to reduce poor team learning performance and exploit team knowledge while improving organizational knowledge assets.

References

[1] R. Ackoff (1999). Ackoff's best: His classic writings on management. New York, NY: Wiley & Sons.

[2] T. Ambos and B. Ambos (2009). The impact of distance on knowledge transfer effectiveness in multinational corporations. Journal of International Management, 15(1), 1-14. doi:10.1016/j.intman.2008.02.002

[3] M. Boisot (1999). Knowledge assets: Securing competitive advantage in the information economy. Oxford, UK: Oxford University Press.

[4] R. Patnayakuni and C. Ruppel (2010). A socio-technical approach to improving the systems development process. Information Systems Frontiers, 12(2), 219-219-234. doi:10.1007/s10796-008-9093-4

[5] E. Salas, S. Fiore, and M. Letsky (2012). Theories of team cognition: Cross-disciplinary perspectives. New York, NY: Routledge.

[6] C. Santos, A. Passos, and S. Uitdewilligen (2016). When shared cognition leads to closed minds: Temporal mental models, team learning, adaptation and performance. European Management Journal, 34(3), 258-268. doi:10.1016/j.emj.2015.11.006

[7] F. Sexe (2012). Implementing a learning and adaptation system to improve team effectiveness. Proceedings from the ASEM National Conference.

[8] F. Sexe (2016). Exploring the relationship between social distance and knowledge sharing in virtual teams: A regression study (Doctoral dissertation). Available from ProQuest Dissertations and Theses Global. (1842427231). Retrieved from http:// http://search.proquest.com.ezproxy.snhu.edu/docview/1842427231?accountid=3783

[9] K. Vicente (1999). Cognitive work analysis: Toward safe, productive, and healthy computer-based work. Boca Raton, FL: CRC Press.

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