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Technology-Mediated Learning: A Comprehensive Theoretical Model *

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Abstract

Increasing organizational investment in technology for training and learning underscores how important it is for researchers to understand and investigate technology-mediated learning (TML). However, the limited empirical data in this area fails to provide a consistent and comprehensive picture of the TML phenomena. A critical aspect missing from existing research is the focus on the learning process. In this paper, we articulate a theoretical model, based on Adaptive Structuration Theory, for TML that explicitly configures elements of the learning process, including team, technology, and learning technique structures. Existing TML research from the information systems (IS) and education literatures is summarized and research gaps are identified. The paper not only helps to explain inconsistencies in previous research, but also develops specific propositions for future research. The propositions stated in the paper represent the theoretical relationships among the constructs in the TML model. The model provides a vehicle for researchers, both in IS and education, to summarize and integrate existing research and theories and to guide future research in this important area.

Keywords: *Technology-Mediated Learning, TML, Computer-based learning, Computer-mediated communication and collaboration, Learning, Training, Adaptive Structuration Theory, AST, Theoretical Model*

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Technology-Mediated Learning: A Comprehensive Theoretical Mode

1. Introduction

With an increasing number of organizations focusing on internal capabilities for success, training is no longer a cost center but a strategic center. Training is one of the most common methods companies employ to enhance the productivity of individuals and to communicate organizational goals to new personnel. A recent meta-analysis reported a medium to large weighted effect size on behavior or skill change in business organizations (0.60 to 0.63) (Arthur et al., 2003). Two important trends in the training area are: 1) the influence of technology in all learning scenarios referred to as technology-mediated learning (TML), and 2) the move toward more social forms of learning (Arthur et al., 2003).

The trend in TML investment is highly visible in both organizations and academic institutions. In 2008, U.S. organizations with 100 or more employees spent $134.39 billion on formal training, with 32.6 percent of it done through technology meditation (ASTD, 2008). By year-end 2009, Gartner predicts that 60 percent of core business processes and software will include a TML component (Gartner, 2004). Similarly, in 2004, over 90 percent of all public institutions offered some form of technology-mediated courses (Sloan-C, 2004). TML also has many variations and is often a combination of the following learning modes (blended learning): web-based or computer-based, asynchronous or synchronous, instructor-led or self-paced, individual-based or team-based. For example, a virtual classroom is a web-based synchronous tool that is instructor-led and could be used for individual or team-based instruction.

In spite of this growth in TML, it has only recently attracted the attention of Information System (IS) scholars, although the topic has been consistently of interest to Education researchers. Education researchers have focused on grades K-12, while most IS research has been concerned with TML in work places, although college students and contexts are often used in studies. Thus, there is little TML research that takes place in organizational-based settings. Moreover, there is little cross-referencing of research in education or IS and few collaborative efforts between the two disciplines. The research done so far is limited, inconsistent, and still lags behind developments in practice (Alavi and Leidner, 2001, Sasidharan and Santhanam, 2006).

The initial focus of TML in the education literature has been on its impact on individual learners. However, a review of the literature points out that learning strategies have shifted toward more active and team-oriented learning (Alavi et al., 1995, Johnson and Johnson, 1999). With advances in information systems, much richer forms of social TML are available such as virtual classrooms, asynchronous learning networks, e-apprentice training, etc. Some researchers have postulated that team-based TML is likely to become the most predominant and effective way of learning (Jokela, 2003). However, the limited IS (summarized in Gupta and Bostrom (2008)) and education studies related to TML (summarized in Lehtinen, et al. (2003)), have found mixed results of the impact of TML at the individual as well as the team level.

One explanation for these mixed results is that most studies in this area have used input-output research designs that ignore critical aspects of the learning method and process (Alavi and Leidner, 2001). Recent articles in both the IS and educational literature have argued that our focus needs to change to the learning process (Alavi and Leidner, 2001, Hannafin et al., 2004). The problem, however, is that there is no good comprehensive theoretical model to guide research efforts in this area.

This paper provides such a model. We begin the paper by outlining the model development process and the need for a theory-based model, highlighting the key assumptions that need to be accounted for in a theoretical TML model. Section 2 outlines the process of theory development. Section 3 highlights the major research gaps, and how the proposed model addresses them. In Section 4, we describe the model, outlining the various constructs and the relationships among them in the form of propositions. We utilized Adaptive Structuration Theory (AST), a useful meta-theory, as well as findings from TML research, to develop the research model and propositions. The goal is to formulate general propositions for the TML system. The model also provides a nomological framework that can be used to integrate varied theories and results related to the TML. We conclude the paper by providing an example of operationalizing the model and providing guidance to TML researchers based on the model and propositions.

2. Theoretical Development

We followed the three-step process outlined by Weick (1989) in developing the theoretical model**:** 1) outlining a problem, 2) reviewing the diverse conjectures in the literature, and 3) developing criteria for selecting a theoretical perspective.

The major problems encountered in our literature review were the lack of agreement on the scope of TML and the lack of a good comprehensive theoretical model. Previous research has conceptualized TML as being synchronous, asynchronous, or blended learning. Combining these views, we use Alavi and Leidner's (2001) comprehensive definition of TML as "*an environment in which the learner's interactions with learning materials, peers, and/or instructor are mediated through advanced information technology*."

IS researchers also suggest that to understand a technology-based phenomenon such as TML, theoretical models need to include all the elements of a social-technical system: technology and learning techniques, process, actors, actions and outcomes (Bostrom et al., 2009, Zmud et al., 2001). Thus, to deal with the second problem of a well-developed theoretical model for TML, the challenge was to come up with a model encompassing these elements.

We found two philosophical camps in our review of IS and Education literatures: the structuralist and the voluntarist. The structuralist approach, also referred to as the deterministic, contingency, or variance approach, has been the dominant approach in the IS area (Weber, 2004). This research approach assumes that factors not controlled by the actor or learner heavily determine the outcomes from a system. The learner's choices are assumed to be illusionary, marginal, and/or trivial (Piaget, 1970). Researchers in this camp have focused on various learning methods and individual differences (for a review of literature from this perspective see Fjermestad, et al. (2005), Gupta and Bostrom (2008), and Bernard, et al. (2004)). As pointed out in the referenced reviews, results based on this approach have not been consistent, and there is a lack of good theoretical frameworks to guide and integrate research.

Research in TML using the voluntarist approach, usually referred to as the process approach, is limited, especially in IS. However, it is the dominant approach used in education and educational psychology. This research assumes that the learner makes real choices and influences outcomes. The approach argues for a focus on the role of the actors or learners (Giddens, 1984). Recent research in this area has developed the emergent perspective in education (Jonassen and Reeves, 2001) and the user-centric agenda in IS (Sasidharan and Santhanam, 2006). These approaches, however, tend to ignore the role of external influences on the learning outcomes (Hansman, 2001). As with the structuralist approach, there is a lack of theoretically grounded frameworks in this camp.

Last, an important philosophical conjecture rarely examined by either camp is "*reciprocal causation."* This assumption states that actors and structures interact with each other to generate new system features constantly (Giddens, 1984). The result of this interaction has an influence on the outcomes of the learning system. Although rarely included in research models, this assumption is central to multiple learning theories such as social cognitive theory (Bandura, 2001) and social development theory (Vygotskiæi and Cole, 1978) as well as in IS concepts such as duality of technology (Orlikowski, 1992).

For the development of the theoretical model, Weick's third step involves identifying criteria for selecting the relevant theory from the literature. While both philosophical approaches discussed above have their strengths, neither alone provides an adequate explanation for exploring the TML phenomenon. An integrative research perspective is needed to include both structural and process perspectives as well as to incorporate the assumption of reciprocal causation. Since we could not find a specific theoretical framework in the literature that satisfies the above needs, we focused our efforts on finding an appropriate meta-theory rather than a single theory. A meta-theory outlines an ontological network of constructs and relationships applicable over several areas of investigation (Milton and Kazmiercak, 2006, Straub et al., 1995). Ritzer (2001) identified the following primary criteria for selecting a good meta-theory:

1. Ability to facilitate theory development: Meta-theory should provide a lens through which one or more types of context can be understood. It should provide an understanding of the assumptions, constructs, and their relationships that can be applied to generate expectations about the workings of a given context. A good meta-theory describes, prescribes, and gives direction to what is acceptable and unacceptable as a theory.
2. Ability to provide overarching perspectives: Meta-theory should serve as a framework for developing overarching perspectives for a domain. A meta-theory should also have the ability to synthesize the empirical and conceptual work into a coherent frame for simultaneously understanding them (Utåo, 2005)

Adaptive Structuration Theory (AST) (DeSanctis and Poole, 1994), when viewed as a meta-theory, satisfies the criteria outlined above. Examples of successful theory development in specific context (Criterion 1) using AST already exist in the literature, e.g., Poole and DeSanctis' (1992) model focusing on a Group Support Systems context, a model for group decision-making using Geographic Information Systems (Jankowski and Nyerges, 2001), and Thomas' (2005) model of project leaders' facilitative actions adapting new technology in a virtual team context.

AST also provide researchers the ability to examine both what is known and what is unknown from this overarching perspective (Criteria 2 above), and also the ability to evaluate where their future contributions would be most valuable. One example of such an application occurs in the virtual teams domain, where existing literature was mapped using AST constructs in order to examine what sorts of studies have already been conducted and to identify key research areas (Thomas et al., 2007).

Table 1: Need for a comprehensive TML framework

Concerns in literature	What our model will do for TML research
There is no comprehensive theoretical framework to guide and integrate TML research.	Our model provides a nomological framework grounded in AST that provides an ontological framework of constructs. It provides the ability to integrate the current conjectures in research.
Multiple specific theories exist to understand specific aspects of learning.	The model provides the capability to integrate variance and process theories to generate specific falsifiable hypotheses, while still providing a method to integrate research results into a larger framework.
Previous TML studies, even when analyzing similar phenomena, have yielded inconsistent results.	The model provides a method to explain the varied results by scaling the structural dimensions involved in the learning methods.
Previous TML studies tend to use input-output research designs that do not focus on the learning process.	The model provides a unique way for understanding the learning process using concepts of appropriation and reciprocal causation.
Current research ignores the concepts of learning goals and epistemological perspective of the designer/teacher.	The model integrates the epistemological perspective of the instructor/designer and learning goals and outlines how it influences the learning method design using the AST construct of "spirit."

3. The Need for a Theoretical Model of TML

Besides the lack of a comprehensive framework outlined above, many other motivations exist for the development of the framework presented. Table 1 summarizes the current concerns in the TML literature as well as how the presented model resolves them. The nature of research in TML has resulted in researchers using multiple theories to understand a specific phenomenon. While this enriches the discipline, it also leads to fragmented and non-generalizable results. The problem is compounded when the use of similar looking TML tools results in inconsistent effects on learning outcomes. The framework presented provides the ability to integrate multiple theories, as well as a method to scale the TML tools. In addition, two important areas ignored by the current research are the learning process and the epistemological perspective of the designer/teacher. The framework described in the subsequent sections addresses the concerns outlined in Table 1.

4. AST-Based Theoretical Model of TML

Poole and DeSanctis (2003) identify seven requirements and a process for applying AST effectively: identification of structures, relationship among structures, description of the social system, appropriation of the structures, influence on social context or reciprocal causation, influence of actors and power dynamics. We followed these seven requirements and the process in the development of our TML model. Researchers often have a hard time with the language or terminology of AST. To alleviate this, we created Appendix 1, which contains a list of key terms, definitions, and section references that readers can use to check term definitions when they get lost or confused.

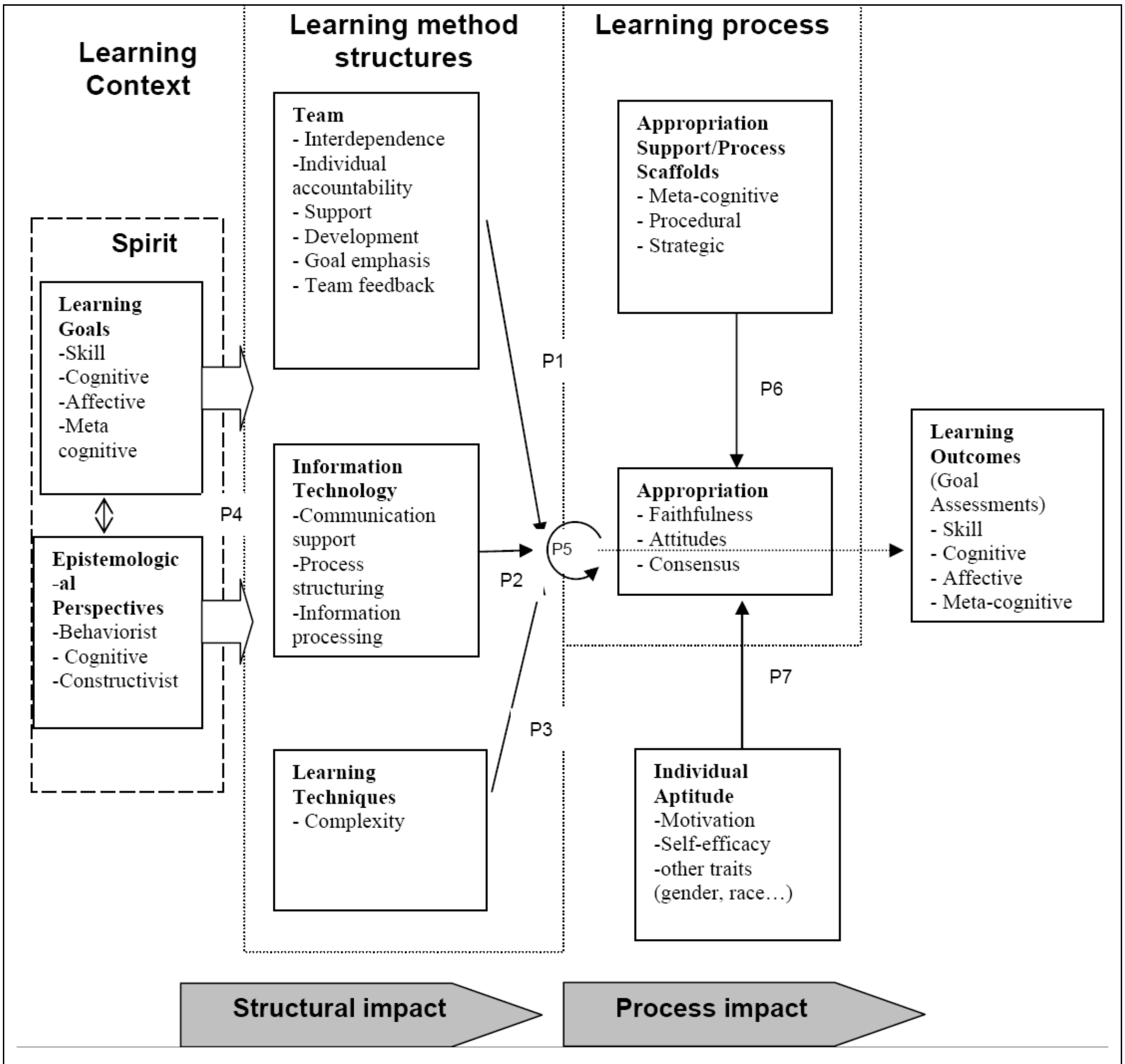

Figure 1: Conceptual Model of Technology-Mediated Learning

AST is built upon two basic premises. The first premise relates to the influence of structures embedded in a context. Structures are rules, resources, and capabilities embedded in a context (DeSanctis and Poole, 1994). While many such structures exist in a TML context, the impact of the learning method or instructional method is the prime candidate of interest. In our TML model outlined in Figure 1, we conceptualize the learning method in terms of three sets of structures: the team or the social setup of the team (Johnson and Johnson, 1999); information technology or the array of possible uses of technology (DeSanctis and Poole, 1994); and learning technique or the specific procedures used to attain learning goals (Schunk, 2004). Together, they form the structural potential of the learning system. If a particular structure set is not being used, e.g., collaboration or team-based learning, the set would drop out of the model. The model states that the structures of the learning method and the interactions among these structures influence the learning process (Orlikowski, 2000).

AST states that in a directed or purposeful social system, external structures reflect the values and norms of the designer, i.e., they are designed to reflect a spirit. The spirit is the *"official line"* that the learning method presents to the participants regarding how to act, interpret the features, and fill in the gaps in the procedures that are not explicitly specified (DeSanctis and Poole, 1994). In the TML learning model outlined in Figure 1, the spirit is derived from the learning goals and epistemological perspective taken by the designer (Leidner and Jarvenpaa, 1995, Reeves et al., 2005).

The second premise, capturing the rest of the requirements, relates to the learning process. It states that actors, learners in this case, are purposeful in their actions and interact with the structures through the process of appropriation, i.e., a process where participants learn and adapt the structures based on their interpretation of the spirit (Poole and DeSanctis, 2003). The structures outlined above are produced and reproduced through interactions with learners. The learning process, thus, incorporates reciprocal causation (represented with circular arrow overlapping the line between structures and process boxes in Figure 1), where the appropriation at any time influences structures, which, in turn, influence appropriation in the next cycle. The learning process is also influenced by the scaffolds present as well as individual aptitudes of the learners.

Drawing on these foundations of AST, the theoretical model presented in Figure 1 takes a joint application perspective. The deterministic perspective, primarily from a positivist view, focuses on the structures and their influence on the learning process. Process research would focus on the process box in Figure 1 and would investigate relationships with other model components from this perspective. The learning outcomes represent the goal assessment or measures for determining the success of a learning program.

The next sections discuss each of the major components of the TML model in depth: learning context, method and process.

4.1. Learning context

A basic tenet of learning theory and AST is that the context of learning is enormously important (Merriam and Caffarella, 1999, Poole and DeSanctis, 2003). The learning context is all the elements of the environment that enable or constrain learning. Merriam and Caffarella (1999) pointed out that researchers should analyze the influence of context on learning using two perspectives: the interactive and the structural. Our model captures the interactive perspective in the learning process, and captures key contextual elements as structural inputs (see Figure 1): learning method, scaffolds, and individual differences.

It is still important in an AST perspective to examine other key contextual factors, not captured in the input structures, that might influence the process. Educational research has typically focused on race, class, cultural diversity, and power/oppression (Merriam and Caffarella, 1999). Many race and class issues are also related to the power factor. The power factor seems to be central for the critical theory literature in both education and IS. Poole and DeSanctis (2003) include critical inquiry into power dynamics as one of their seven requirements for fully realizing an AST research agenda.

Since the focus of this paper is on learning method and scaffolds, power and the other context variables will not be discussed in depth. These context variables can be investigated as structural inputs or just included as context variables in the TML model. The intent of this section was to highlight their importance.

4.2. Spirit

As outlined in Figure 1, the learning goals and epistemological perspectives together form the spirit of the learning method and guide the choice/design and implementation of the learning method. The *spirit* comprises the goals, values, and assumptions about knowledge that influence the design of the learning method. The instructor or instructional designer primarily influences the learning process by applying his or her *spirit* to the design of input structures: learning method and scaffolds (illustrated in Figure 1 as large box arrows).

Although AST conceptualizes spirit as an important construct, researchers have failed to adequately focus on it (Poole and DeSanctis, 2003). This is true for TML research also. Educational literature discusses the attitudes/beliefs of the instructor (Kollias et al., 2005), the changing role of the instructor (Berge, 1995), and epistemological perspectives quite a bit, although they seldom show up in research studies. It is, however, important that the researchers recognize the underlying spirit so that the assumptions, subsequent structures, and the learners' actions can be evaluated from the right perspective. This section expands the discussion on spirit within AST by providing a detailed example of developing the concept of spirit for the TML context. Such an analysis can be extended to other contexts besides learning.

4.2.1. Learning Goals

Learning goals comprise the knowledge expected to be attained as a result of the learning/training process (Kang and Santhanam, 2003, Sein et al., 1999). Research in educational psychology classifies learning goals into four categories: skill, cognitive, affective, and meta-cognitive (Anderson and Sosniak, 1994). Skill goals focus on imparting procedural knowledge or know-how, cognitive goes focus on building a broader domain knowledge in a subject area, affective goals focus on enhancing the level to which the learner is immersed in the subject, and meta-cognitive goals focus on enhancing the learner's ability to understand his/her own learning and information processing procedure (Gupta and Bostrom, 2008).

The progress more toward achieving these learning goals is measured as outcomes of the learning process (See Figure 1). While instruments exist to measure some affective and meta-cognitive outcomes (e.g. satisfaction and self-efficacy scales, respectively), there are limited guidelines for measuring cognitive and skill goal. Researchers have used quizzes, task performance, and job performance to measure cognitive and skill goal accomplishment.

The choice of the goals to focus on is dependent on the designer's view of the target participants' needs. TML research literature and training practices have almost exclusively stressed skill-based goals, and, to some extent, cognitive goals. Future research needs to take a more comprehensive perspective including other forms of learning goals.

4.2.2. Epistemological perspectives

Epistemology describes overarching beliefs about the nature of knowledge and about what it means to *know* something (Hannafin et al., 2004). It provides a design template for creating process and content structures embedded in the learning method. We utilize the most common classifications in both IS and education literatures: behaviorism, cognitivism and constructivism (Leidner and Jarvenpaa, 1995, Mowrer and Klein, 2000). This classification represents a comprehensive and mutually exclusive framework.

The behaviorist view is based on the assumption that human behavior is predictable. Under this theory, learning occurs when new behaviors or changes in behaviors occur as the result of an individual's response to stimuli. Thus, the end goal is defined up front, and each step necessary to achieve the goal is given to the learners (Burton et al., 2001). For example, direct instruction, which is the most popular form of learning method, is based on this perspective.

The cognitivist perspective holds that learning is a process that is dictated by the participant's cognitive structures and how the information is presented to the participant. Under this perspective, learning is a change in knowledge brought about by modified mental representations. Thus, tasks under this theory have a predefined goal along with information necessary to reach the goal, but the process of cognition of the information is left to the learners (Winn and Snyder, 2001). Learning methods based on cognitive perspective often include behavioral modeling.

From the constructivist perspective, individuals construct knowledge by working to solve realistic problems. Under this perspective, learning is the process whereby individuals construct new ideas or concepts based on prior knowledge and/or experience. A constructivist designer usually provides all the information necessary for learning but allows the learner to absorb the materials and information in a way that is most comfortable and to arrive at their own conclusions. Learners are presented with an idea about the solution and the tools necessary are provided. However, the learners are left on their own to figure out the exact solution, and the process required to reach it (Duffy and Cunningham, 2001). An example of a learning method based on this approach would be an unguided case study or project work.

As shown in Figure 1, the choice of the epistemological perspective and learning goals provide the foundation for learning method design choices. Different epistemological perspectives and learning goals imply different assumptions about how knowledge is gained. Thus, they lead to different learning method designs. For example, Alavi (1994) based the design of the GDSS-based learning method on a cognitive perspective and focused on learning skills.

4.3. Learning Method: Features and Dimensions

A learning method is defined as a combination of structures that guides individuals to achieve the learning outcomes. DeSanctis and Poole (1994) state that technology structures can be described in terms of their features and dimensions. We argue that this perspective can also be used to understand the other structures in a learning method: team and learning techniques.

Structural features are the specific capabilities offered by structure (DeSanctis and Poole, 1994). In an information systems context, these are also referred to as functionalities, and have been the focus of development and marketing efforts. For example, Internet Explorer 8 has features like tabs, search suggestions, accelerators, etc. However, the same features can be implemented in a variety of ways in different situations and in different software, often leading to very different perceptions. These implementation differences have led to research outcomes that are not generalizable and are difficult to compare.

To resolve this problem, AST uses dimensions to describe structures. A dimension describes an aspect or characteristic of a structure or set of structures (DeSanctis and Poole, 1994). Dimensions are scalable, reflecting the amount of a given characteristic manifested in the structure. Scaling of dimensions can be accomplished by consulting manuals, reviewing the statements of designers, and educators, or noting the comments of participants (DeSanctis and Poole, 1994).

One or more features create a particular level of a dimension. Dimensions answer the question: What do these features do for the actor/learner? For example, Silver (1991) used the dimension of restrictiveness to differentiate among decision support systems. Restrictiveness measures the degree to which the features of a system limit the decision-making process. Silver used features such as ability to show a spreadsheet, implement functions, and execute programming code to measure the restrictiveness of a decision support system. The absence or presence of these features creates a particular level of system restrictiveness.

Much of the learning research, including TML, has also focused on the features in learning methods

(Gupta and Bostrom, 2008, Lou et al., 2001) and has arrived at similar non-generalizable results. For example, case studies have been broadly classified as McAleer Interactive Case Analysis (MICA) and Harvard Case Method (HCM), depending on the following features: role of the instructor, type of participant, and the case guidelines (Desiraju and Gopinath, 2001). Although useful in understanding the two different case study methods, the Desiraju and Gopinath (2001) study comparing MICA and HCM failed to attribute the learning differences to these features.

The focus on dimensions, instead of features, helps us not only in enhancing our understanding of learning methods, but also in developing hypotheses and explaining research results. In the above example, Desiraju and Gopinath (2001) were able to explain the study results by focusing on the dimensions of feedback and restrictiveness of the case-based learning methods.

The above discussion highlights the need to focus on structural dimensions. Next, we expand on the three structural sets of a TML method: information technology, teams, and learning techniques.

4.3.1. Information Technology Structures

Information technology has been widely used in learning methods. This use could be a singular computer application or a combination of computer applications. A meta-analysis on the effectiveness of computers in education has shown that, in the majority of studies, the use of technology has improved learning outcomes (Kovalchick and Dawson, 2004). However, the meta-analysis did not distinguish between the various pedagogical uses of technology, confounding the results. When distinguished based on pedagogical uses, the results present a different picture (Jonassen and Reeves, 2001).

Information technology use can vary based on two kinds of applications: learning-from-computers and learning-with-computers. These applications can be used to support individual or team-based learning. Learning-from-computers occurs when the computer is the medium of instruction (e.g. computer-based training). Research comparing the effectiveness of individual learning-from-computers to standard methods of instruction has provided inconclusive results in both education (Kovalchick and Dawson, 2004) and IS literature (Gupta and Bostrom, 2008). Though initial results in team-based learning-from-computer treatments are positive (Kovalchick and Dawson, 2004), there have been few such studies in both IS and education.

Learning-with-computers occurs when information technology is used as a tool to support learning (e.g., use of a website by instructor or use of collaborative technology). An Educational meta-analysis at the individual level showed that learning-with-computers had a positive impact (Kulik, 1994). However, an educational meta-analysis of team-based learning-with-computers shows inconclusive results (Strijbos et al., 2004). Within IS, research results of learning-with-computers studies have been inconclusive at both individual and team levels. For example, at the individual level, Zhang et al. (2004) found a positive impact, whereas Piccoli et al. (2001) did not, except for an increase in self-efficacy. At the team level, Leidner and Fuller (1997) found a positive impact of the use of collaborative technology, but Hiltz et al. (2000) and Alavi (1994) did not.

As stated earlier, rather than focusing on the features of information technology in each pedagogical use, we need to shift our focus to structural dimensions. Information technology can affect the levels of learning method dimensions, or it can provide dimensions that do not exist in non-computer methods. Based on a review of the literature, we have identified several dimensions listed in Table 2, broadly classified by type of technology: communication support, process structuring, and information processing (Zigurs and Buckland, 1998). For example, the GroupSystems© brainstorming tool features the ability for participants to provide simultaneous input. This input can be anonymous or not, varying the degree of anonymity. Thus, we can use the simultaneity and anonymity dimensions to describe this brainstorming tool independent of the features used to implement the tool. The list in Table 2 does not represent an exhaustive list of dimensions, and research exploring new dimensions is needed.

Table 2: Information Technology Structures: Features and Dimensions

Structural Characteristics	***Communication Support***	***Process Structuring***	***Information Processing***
Dimensions	Synchronicity Anonymity Simultaneity Interactivity Telepresence Richness	Restrictiveness Self-directivity / learner - control Flexibility Synchronicity	Comprehensiveness Sophistication Feedback Personalization Authenticity
Features examples	Chat Email Audio/video/text Brainstorming	Scheduling Syllabus and course organizer Learning sequence	Voting Decision tools Simulated environment

These structural dimensions can be applied to both forms of TML. In a learning-from-computer use, the learning technique is incorporated into the information technology integrating the two structural sets (see Figure 1). In a learning-with-computer use, structural dimensions of the learning technique are supplemented (enhanced) by the use of technology. Thus, similar to design theorists (Hevner et al., 2004, Reeves et al., 2005), we contend that it is not the technology or the features of technology that are important, but rather the structural dimensions that the technology provides, which influence learning effectiveness.

The dimensions used to develop specific hypotheses need to be based on or derived from learning theories. The learning theories used must have theoretical and possibly empirical support for specific learning outcomes being researched. We contend that when these dimensions are drawn from supported learning theories, specific learning outcomes will be positively affected.

> **P1:** *Ceteris paribus, the more the structural dimensions of TML technology manifest supported learning theory, the greater the technology's impact on learning outcomes.*

To operationalize the proposition and understand the impact of a TML software tool, researchers will need to analyze the structural dimensions embedded in it and map them to the learning theory being used to investigate the TML tool. The explicit assumption in the model is that technology can be used to support learning theories that take any of the epistemological perspectives discussed previously. However, the form of the technology is likely to be very different for different perspectives. There are examples of technology supporting each of the perspectives in the literature. We illustrate the implementation cognitive perspective below and the constructivist perspective later in the paper. Similar investigations can be done for other perspectives.

Most business and academic organizations use a TML web-based system, especially for end-user training such as training in Microsoft Office. These systems demonstrate actions followed by an opportunity to replicate the actions in a simulated setting. These systems have been researched primarily using social cognitive theory (SCT) (Gupta and Bostrom, 2008). SCT focuses on two types of general learning methods: 1) observation of others' actions or vicarious learning and 2) observation of self-actions, or enactive learning (Schunk, 2004).

The first part of proposition P1 deals with outlining the embedded structural dimensions. Drawing on the education and IS literatures (Gupta and Bostrom, 2008), we identified four core dimensions of vicarious learning: realism, authenticity, model credibility and restrictiveness. Similarly, we identified seven core dimensions of enactive learning: production pattern, structuredness of practice, restrictiveness of practice, feedback, guidance, richness, and authenticity (see Table 3). Description of each of these can be found in Gupta & Bostrom (2008) and Schunk (2004). The various TML tools that are based on SCT can be distinguished based on the levels of each of these dimensions.

The second part of proposition P1 argues that higher levels of these dimensions represent a better implementation of the theory and, consequently, should result in higher levels of learning outcomes. Thus, a general hypothesis drawn from the above argument would state: "*Individuals in using TML* *tools with higher levels of the SCT dimensions outlined above will perform better on learning outcomes".*[1] Gupta (2008) conducted a study comparing a web-based training tool (elementK) method that had higher levels of enactive structural dimensions with a video training learning method. We have included Gupta's comparison of the two learning methods on the enactive learning dimensions to illustrate how dimensions can be used to distinguish between different learning methods (See Table 3). The study supported the hypothesis, confirming proposition P1 outlined above.

Table 3 : Enactive Learning Dimensions

Enactive Learning Dimensions	Video treatment Scale of dimensions & features used to implement	WBT treatment Scale of dimensions & features used to implement
Production Pattern: The lag between demonstration of an action and practice by the learner (Schunk, 2004).	**Delayed Production** - All procedural/behavioral and declarative knowledge given to the students before practice	**Immediate Production** - "Show me" and then "I do" strategy (student presented with small amount of content and then they practice immediately with system providing specific feedback)
Structuredness of Practice: The extent to which technology imposes its procedures on the learner (Poole and DeSanctis, 1990)	**Low** - Practiced what they wanted to or what they remembered	**High** - Practiced specific things demonstrated and given structured exercise to do
Restrictiveness of practice: The degree to which a system limits an action (Silver, 1991)	**Very Low** - Students had total control of their actions	**Very High** - Student actions were guided by the system
Feedback: The degree to which a system provides a response, including correction, addition or approval and speed of response (Desiraju and Gopinath, 2001, Piccoli et al., 2001)	**Low** - Immediate feedback provided by the system - Feedback restricted to syntax and schematics and not tied to learning goals	**Very High** - Immediate feedback provided based on student action - Feedback linked to learning goals
Guidance: The degree to which a system provides direction or advice towards a course of action (Desiraju and Gopinath, 2001)	**Low** - Restricted to what the system provided and not linked to learning goals - Student may not be able to recover and must start over	**Very High** - Directly linked to learning goals - System provided guidance to help students recover and correct their action

This perspective and analysis can be extended to other existing TML tools, other learning theories involved as well as other underlying dimensions. In the Gupta study, the TML tool was selected because it included features that implemented enhanced enactive learning.

4.3.2. Team Structures

Teams provide an environment where participants draw on each other for social understanding, observations, and reflections. In a comparison with traditional classroom learning, researchers found that the team-based approach increased participant involvement, increased the level of critical and active thinking, promoted problem-solving skills, and improved participant satisfaction (Lou et al., 2001, Rohrbeck et al., 2003).

However, meta-analysis of team-based learning studies shows a very high variance in the effect size (Lou et al., 1996, Springer et al., 1999). The results are even more varied in a TML scenario, ranging from negative to positive (Lehtinen et al., 2003, Lou et al., 2001). Business researchers have also conducted an extensive amount of research into the function of groups (Chidambaram and Bostrom, 1996, Fjermestad and Hiltz, 1998, Hackman, 2002). Much of this literature is directly pertinent to

[1] For more specific hypotheses, see Table 6 in Section 5.1.1. In Section 5.1.1, we discussed the Gupta study in more depth.

learning groups because it identifies important features of high performing groups, such as common goals and norms, clear roles, certain group size, leadership, and so forth (Beebe et al., 2007, Hare, 1994). Similar to the learning literature, business research has resulted in a high degree of variance.

An important reason for variance, similar to the reason for variance in TML results, is the focus on collaboration method features rather than the structural dimensions (Johnson et al., 2000). Drawing from team research in Education (Johnson and Johnson, 1999) and Management (Franklin et al., 1976), we identified six important structural dimensions that differentiate learning teams: interdependence, accountability, support, identity, goal emphasis, and team feedback. Similar to Table 2, Table 4 describes the dimensions associated with team structures and examples of features that could be used to implement these dimensions.

Different collaboration methods focus on different dimensions, and, thus, create different levels of richness in these dimensions. However, as argued earlier, the greater the level of the team dimensions, the greater the effectiveness of collaborative learning. Although direct empirical research has not been done to test all the structural dimensions in a single study, a post-hoc meta-analysis of the Education (Johnson et al., 2000) and organizational literatures (Chidambaram and Bostrom, 1996, Chidambaram and Bostrom, 1997) provides evidence to support the positive influence of these dimensions on outcomes. Although done in different contexts, researchers cited as references in Table 4 have developed a program of research around the referenced dimensions respectively, and provide considerable evidence regarding their effectiveness.

Table 4: Team Structural Dimensions and Features

Team Dimensions	***Definition***	***Features used to implement***
Positive Interdependence ***(Johnson and Johnson, 1999)***	Perception of the degree to which participants are linked in a way that some benefit is accrued to the collaborating individual	Resource interdependence through common assignments and computer use
Individual Accountability ***(Franklin et al., 1976)***	Degree to which the performance of each individual participant can be assessed, and feedback is seen by the team as well as the individual.	Using an average score to reflect the score of each individual in the team
Support ***(Vygotskiæi and Cole, 1978)***	Degree to which participants offer useful help to fellow team members, or provide information that may be useful in understanding a concept.	Peers encouraged to help each other when they had questions
Development ***(Vygotskiæi and Cole, 1978)***	Degree to which the interactions among participants promote an effective working team	Ground rules based on reciprocal questioning were introduced
Goal Emphasis ***(Franklin et al., 1976)***	Degree to which participant behavior is focused on accomplishing team goals	Reciprocal questioning between peers to assess how well each is learning
Team feedback ***(Johnson and Johnson, 1999)***	Degree to which team members discuss how well they are achieving their goals and maintaining effective working relationships	Teams discussed how well the team was performing on the assignments

Thus, for teams to have interaction that positively affects individual learning, collaboration methods need features that enhance the dimensions mentioned above. A recent meta-analysis comparing collaboration learning methods provides evidence in this area to suggest that collaboration learning methods with higher perceived levels in team dimensions showed the largest effect size on learning outcomes (Johnson et al., 2000).

> **P2:** *Ceteris paribus, learning methods manifesting higher levels of the structural dimensions outlined in Table 4 will have greater effectiveness in terms of learning outcomes.*

The support for this proposition is best illustrated in a comparison of studies outlined in Gupta (2008) and Davis and Yi (2004). Both studies focused on EUT and both used dyads. However, while Davis and Yi (2004) did not find any positive effect of collaboration, Gupta (2008) found positive results. This difference can be explained by the manner in which the later study developed teams using reciprocal questioning (as illustrated in King (1990)) and other group development techniques to operationalize the structural dimensions mentioned in Table 4. Consequently, the positive effect of dyad-based training may be explained.

4.3.3. Learning Techniques Structures

Learning techniques are specific procedures and tasks needed to attain learning goals (Weinstein and Mayer, 1983). The structural dimensions we discussed in the technology and collaboration sections also apply to learning techniques. However, there are also certain dimensions that are specific to the learning techniques. One such dimension that has received particular attention in education research is learning technique complexity (Maynard and Hakel, 1997). In this section, we will focus on this dimension to illustrate how to fully define or scale a dimension.

The complexity dimension deals with the level of critical thinking and number of decision factors that participants need to go through as they perform a learning technique. In an effort to scale the degree of complexity, some Educational researchers have focused on technique arrangement, familiarity and difficulty (Lou et al., 2001), while others have focused on subjective and objective complexity (Maynard and Hakel, 1997). Campbell (1988), in a literature review, presented an integrative method to scale the degree of complexity.

Campbell (1988) described the degree of complexity in terms of the following: 1) outcome multiplicity: or the number of correct outcomes possible; 2) solution scheme multiplicity: defined as more than one possible way to achieve the outcome; 3) conflicting interdependence: adoption of one course of learning conflicts with another; and 4) outcome uncertainty: the degree to which learning outcomes are specified. Different combinations of these factors provide us with a way to categorize the complexity of learning techniques into five levels (see Table 5) (Campbell, 1988).

Table 5: Learning Techniques - Complexity Dimension Mapping

Features\complexity	***Simple***	***Problem***	***Decision***	***Integration***	***Fuzzy***
Outcome multiplicity	No	No	Yes	No	Yes
Solution scheme multiplicity	No	Yes	No	No	Yes
Conflicting interdependence	No	Yes or no	Yes or no	Yes or no	Yes or no
Outcome uncertainty	N.A.	Low to high	Low to high	Low to high	Low to high
Learning technique example	*Reciprocal questioning*	*Application Exercise*	*Case study*	*Jigsaw Procedure*	*Projects*

Low levels of complexity or simple learning techniques have a single desired outcome, a single solution scheme, and no conflicting interdependence or outcome uncertainty. A classic example of this in a team setting would be a structured reciprocal questioning method (King, 1990), where team members go through a pre-defined process to achieve specific learning outcomes. For learning techniques in the problem category, the focus is on finding the solution to a problem to accomplish a predefined goal, e.g., application exercise. The focus of the decision learning technique is on performing an activity so that it satisfies multiple outcomes. A case study method is a prime example of such a technique. For learning techniques in the integration category, the emphasis is on resolving conflict and uncertainty in information associated with the task. For example, in the jigsaw technique (Aronson and Patnoe, 1997) every participant has a critical piece of information unknown to the rest of the team. Using the unique information from each participant, each team develops a unique solution. Finally, fuzzy learning techniques have very little focus, and team members are allowed to explore and learn on their own, e.g., learning is achieved using real life projects.

The model in Figure 1 shows that the learning goals influence the choice of structural dimensions such as the complexity level of a learning technique. For example, Benner (2004) studied participant nurses at each stage of skill acquisition and found that as a participant moved to a higher level of skill acquisition, a more complex technique was necessary for imparting learning. Drawing on this, we contend that the complexity of the learning technique should be driven by the learning goal associated with a given level of expertise, i.e., for a novice, a simple task is likely to be more effective, while for an expert, fuzzy tasks are likely to be more representative of the intent of the learning goals.
A process similar to the one outlined above can be used to develop other learning technique dimensions such as module size. Similar to our argument in the information technology section, the dimensions used to develop specific hypotheses need to be based on or derived from learning theories. The learning theories used must have a plausible set of underlying arguments and possibly empirical support for the specific learning goals being targeted. We contend that when these dimensions are drawn from supported learning theories, specific learning outcomes will be positively affected. Thus, we postulate:

> P3: *Ceteris paribus, the more the structural dimensions of a learning technique manifest supported learning theory, the greater the technique's impact on learning outcomes.*

The study of learning techniques structural dimensions is especially important in a learning-with-computer scenario (or where no technology is used) where the learning technique is independent of the technology used.

4.3.4. Relationship between structures

Missing from both educational and IS literature is a focus on interaction among structural components of the learning method (Hannafin et al., 2004). One of the seven requirements of applying AST effectively is the development of relationships between structures (Poole and DeSanctis, 2003). The anecdotal research evidence in Education (Lehtinen et al., 2003) and GSS literature (Fjermestad and Hiltz, 1998), suggests that some combinations of structures provide a consistent and clear spirit whereas others do not (Hannafin et al., 2004), thus, outlining an argument for a contingency perspective on interaction (Miller, 1981).

As previously pointed out, the focus of current TML research has been on technology features (e.g., Piccoli et al. (2001), features of asynchronous learning networks) or on team features (Pinsonneault and Caya, 2005). However, we believe the focus needs to shift to understanding the relationship between the structures using structural dimensions. In a learning-with-computers application, technology dimensions should positively support the team structural dimensions outlined above. For example, discussion forums featuring high levels of anonymity discourage the behavior of attacking individuals and encourage participation and the discussion of ideas (Nunamaker et al., 1991). Increased participation and discussion are associated with higher levels of supportive behavior, team development, and team feedback dimensions.

Unlike traditional definitions of fit (e.g., Goodhue and Thompson (1995)), we conceptualize fit as gestalts or the degree of coherence among the set of theoretical attributes (Venkatraman, 1989). Thus, we argue that for effective learning to occur, a learning method needs to reflect the values and assumptions of the epistemological perspective and the learning goals. In other words, the method should have a consistent spirit, across all structures as well as the structures emerging out of their interaction. The three sets of structures — team, learning technique, and information technology — all have to support (or fit with) each other to form a learning method that can enhance learning. Such a conceptualization allows for research to provide useful insights into feasible sets of internally consistent and equally effective configurations of the above mentioned structures (Venkatraman, 1989). Such a design would provide consistent guidance to the learners.

An example of a *mis-fit* is provided in Hiltz et al. (2000). This study used collaborative TML in the form of a virtual classroom. While the pedagogy was designed around team-based learning, encouraging the development of team structures, the use of technology was restricted to simply receiving posted material and sending back individual work, encouraging individual work. This *mis-fit* provided contradictory signals of the underlying spirit to the participants, negatively affecting learning outcomes. A *mis-fit* sends contradictory signals, making use of the learning method more difficult, thus, exerting a weaker influence on learner behavior (Poole and DeSanctis, 1992).

P4: *Learning methods that display a consistent spirit or fit across all structures will have greater effectiveness.*

4.4. Learning Process

The discussion until now has focused on the functional or structural impact of the learning method. The propositions outlined previously assume a successful learning process. AST argues that the process is a strong moderation factor in a social system and needs to be understood (Poole and DeSanctis, 2003). The investigation of learning processes is missing from IS, while in education, process research has focused too much on post-hoc analysis of results or opinions of the researcher (Rohrbeck et al., 2003).

The learning process is viewed as an appropriation or structuration process where participants learn and adapt the learning method structures based on their interpretation of the spirit (see Figure 1). Like all perceptions, this interpretation varies among learners. We believe that it is these differences in appropriation that explain many of the inconsistencies in previous learning research.

We have pointed to the lack of empirical focus in both the IS and education literatures on the learning process. The problem is the lack of good constructs for looking at the learning process from both a structural and a process perspective. We believe AST, particularly appropriation, provides the constructs. Although educational researchers do not have a concept similar to appropriation, they have focused a lot on scaffolding (discussed in a later section) because of its importance. Scaffolding presupposes appropriation of structures/learning methods but focuses on how to guide or facilitate appropriation instead of structural impacts. The concepts of scaffolding and appropriation complement each other and would be useful for investigating use of technology or any other learning method structures.

Assuming that the learning method reflects the values and assumptions of the epistemological perspective and the learning goals (i.e., for well-designed structures), a faithful appropriation occurs when participants' interaction is consistent with the spirit (Poole and DeSanctis, 1992). Faithfulness is not necessarily concerned with the precise duplication of the procedures provided; rather, it is concerned with whether the structures are used in a manner consistent with the overall goals and epistemological perspective. A participant's unique or innovative use of the structures may well be faithful appropriation as long as the use is consistent with the spirit that the learning method intended to promote (Chin et al., 1997).

DeSanctis et al. (2003) illustrate a case of a faithful appropriation of learning method structures based on a constructivist perspective and how such appropriation affects learning outcomes. In this case, EMBA teams faithfully appropriated a group discussion space, using it to manage present activities, monitor progress, take time for sense-making and plan for the future. The team members used a tone of mutual respect and challenge in their discourse and a willingness to modify routines over time, demonstrating high levels on the team dimensions outlined in Table 4. Interactions resulting from faithful appropriation of the technology and team structures were strongly associated with enhanced learning outcomes.

Ironic appropriation occurs when the participants' interactions violate the spirit of the structure with or without abandoning the underlying learning method (Poole and DeSanctis, 1990). In the case of well-designed learning methods, ironic appropriation could introduce internal contradictions within the structures governing interaction. Over time, these contradictions will cause tensions in interactions that might lead to lower effectiveness of the structures. These contradictions must be addressed, detracting the participant(s) from the learning focus, leading to lower learning outcomes. A recent study by Alavi, et al. (2002) highlights this issue where participants using a sophisticated TML system had lower learning outcomes because of lack of faithful appropriation of technology. The teams had to shift their focus towards technology understanding, detracting the team from focusing on learning. Alternatively, in certain instances, especially for poorly-designed learning methods, ironic appropriation might result in unpredicted, but useful usage.

When analyzing technology appropriation, Poole and DeSanctis (1990) suggest three dimensions that indicate appropriation: faithfulness, attitudes and level of consensus. That is, technology structures will only have their intended effect if the design principles are kept intact (faithfulness), if members do not react negatively to it (attitudes), and if members agree substantially over how structures are used (consensus). Learning technique appropriation can also be measured using the same three constructs. Measures for these constructs exist in the literature and they have been predominantly used in the IS research (Salisbury et al., 2002).

Collaborative structures appropriation, however, deals with the perceptions of rules and norms. The level of each of the team structural dimensions during the learning process can be directly measured by perceptual measures. For example, Slavin (1989) found that participants learned significantly more in teams that perceived high interdependence and individual accountability. Thus, perceived richness of each of the structural dimensions suggests how faithfully collaboration structures are appropriated (Gupta, 2008). Gupta (2008) provides an initial instrument for the measurement of the collaborative dimensions outlined in Table 4.

Thus, the structures of the learning method provide a structural potential that participants draw on to interact with technology, technique, and other people (Orlikowski, 2000). Assuming that the learning methods are well-designed, represent a coherent spirit, and are faithfully appropriated, interactions driven by the spirit are likely to emerge and lead to positive learning outcomes. Based on AST, we postulate that the effects of the learning method would be dependent on the extent of appropriation of the structures. Thus, we state:

> **P5**: *Assuming that structures are well-designed, the greater the success of appropriation (faithful, attitude, and consensus), the greater the effectiveness of the learning method.*

Considerable support for the proposition exists in AST literature, particularly the group support systems literature. Indirect support exists in the education literature, especially in the scaffolding literature.

The model in Figure 1 outlines learning methods and the learning process that is applicable to diverse content and to a variety of settings. It focuses on the process structures in the learning method, which is the dominant focus of both IS and educational research, not the content. Although it is beyond the scope of this paper, we need to make it clear, that while there are learning method process structures being appropriated, there is also a content appropriation taking place. The two appropriation processes are interrelated. Most of the specific content-area learning research addresses novice-expert differences and the different strategies that learners use to appropriate content and how these strategies change as skills develop (Schunk, 2004). This research is often based on more general theories of content appropriation such as Piaget's theory of cognitive development, Ausubel's theory of subsumption, and Mayer's theory of assimilation (Schunk, 2004). The latter two theories have been used in IS to provide theoretical explanations of the efficacy of appropriation of conceptual content (e.g., Sein and Bostrom (1989)). The relationship between content and process appropriation is an exciting area for future research.

4.5. Other Antecedents of Appropriation

A fundamental AST concept is reciprocal causation. Structures of a learning method are constituted recursively as participants interact with them (represented by the circular arrow in Figure 1). There is limited empirical research on using AST to study longitudinal change (Jones, 1999). The process of appropriation over time can be characterized by two kinds of dynamics. First, there is a continuous production and reproduction of structures as they are employed, resulting in changes in levels of appropriation, e.g., increases or decreases in the level of appropriation constructs. Second, at certain junctures, major shifts in the learning process can also occur, resulting in new structures-in-use. Participants might drop structures that do not work, or come up with new structures based on experience.

Overall, Poole and DeSanctis (1992) identify nine such structural moves: direct appropriation, substitution, combination, enlargement, constraint, contrast, affirmation, negation, and neutrality. All of these moves result in emergent structures (Orlikowski, 2000) (rather than the initial structures), which, in turn, influence the effectiveness of the interaction process as captured in the earlier proposition. These concepts help explain some of the existing TML studies. For example, in a study of executive MBA teams using group discussion spaces for team learning activities, the participants constrained the use of the discussion board while expanding the role of file storage structures (DeSanctis et al., 2003), thereby influencing the structuredness and restrictiveness dimensions.

The above argument also highlights the need to study the appropriation process longitudinally. Narrower process theories, such as cognitive load theory, theory of sense-making, information processing theory, etc., can be used to explore the interactions and appropriation moves in more depth. Research in this area has been lacking in both the education and IS disciplines.

Two other antecedents that need to be expanded on are appropriation support and individual differences (Figure 1). Both of these have a direct and indirect impact on learning outcomes. The direct impact deals with content appropriation, i.e., the understanding of the learning concepts involved. Content appropriation is reflected in higher performance on learning outcomes. Considerable research has been done in this area in both the education and IS disciplines, especially the investigation of individual differences on learning outcomes. Since our focus in this paper has been on the learning process, we acknowledge this direct impact, but also argue that an indirect impact of these antecedents exists. We argue that process scaffolds and individual differences have an indirect impact on learning outcomes by influencing the faithfulness of process appropriation. This indirect effect through process appropriation has been ignored in previous IS and educational research.

4.5.1. Process Scaffolding

A scaffold provides initial assistance to support learning. Similar to the learning method structures, scaffolds are usually designed by the instructor. Scaffolding gradually fades as learners become more independent, confident, and competent. Much of the educational literature has focused on the effect of these scaffolds on learning outcomes (Hannafin et al., 2004). AST, however, argues that appropriation is the core of a social system. Drawing on this, the model in Figure 1 conceptualizes that scaffolds, rather than affecting learning outcomes directly, influence the faithfulness of appropriation of the learning method structures. The IS literature has not paid much attention to scaffolding, however, the educational literature has shown that scaffolding, as appropriation support, can help ensure a successful appropriation of learning methods.

Three types of process scaffolds have been identified in the IS and education literatures: meta-cognitive, procedural, and strategic (Grise and Gallupe, 1999, Hannafin et al., 2004). Meta-cognitive scaffolds support individual reflection on learning, such as soliciting estimates of current understanding or cuing participants to identify prior related experiences they can reference. Mao and Brown (2005) provide some evidence of the impact of such support on appropriation by looking at how online wizards enhance the learning process.

Procedural scaffolding helps participants make navigation decisions, such as how to utilize available resources and tools. Remidez et al. (2005) show how procedural scaffolds built into technology can enhance trust in virtual teams. Empirical studies in GSS also support the use of procedural scaffolds, especially those provided through facilitation (Dennis et al., 2001).

Strategic scaffolds support participants by anticipating their interactions, such as analyzing, planning, and making tactical decisions. Hilmer and Dennis (2000) used different decision-making techniques in GSS and found positive support for strategic scaffolding. Education researchers also postulate that e-moderating (a mechanism of providing a scaffold using information technology) is a key component of TML (Salmon, 2003). However, no research that we are aware of investigates these (e-) scaffolds in a TML context. As shown in Figure 1, we argue that these scaffolds facilitate the learning process via increasing the appropriation of the structures involved. Thus, we postulate:

> **P6:** *Assuming that the learning method has well-designed structures*, *process scaffolds influence the faithfulness of learning method appropriation.*

Limited TML and reference discipline research (cited above) does provide some evidence that process scaffolds influence learning outcomes. Research now needs to be expanded to explore the effects of process scaffolds on appropriation. This lack of research in this important and emerging area is clearly a research gap that needs investigation.

4.6. Individual differences

Aptitudes are the initial states and abilities of persons that influence behavior, given specific conditions (Ackerman et al., 1999). AST research, however, has paid little attention to these individual differences. Research in educational psychology (classified as aptitude-treatment interaction) suggests that an individual's aptitude has an interaction effect with learning methods on learning outcomes (Ackerman et al., 1999).

Aptitudes can be broadly distinguished into two categories: motivation and cognitive abilities. Motivation to learn is defined as the direction, intensity, and persistence of learning-directed behavior in training contexts (Colquitt et al., 2000). In a meta-analysis of education literature, Colquitt, et al. (2000) found a modest correlation between motivation to learn and learning outcomes. Similar findings exist in IS literature (Yi and Davis, 2003). However, a stronger positive correlation has been observed between motivation and process variables such as *cognitive absorption* or a *state of flow* (Compeau et al., 2005). The level of cognitive absorption affects the attitude toward the learning methods (Finneran and Zhang, 2005), critical in successful appropriation.

Cognitive abilities entail an individual's capacity to perceive, think, and process. Cognitive abilities focused in the learning literature include learning style, self-efficacy, and learning orientation. The first two have been found to have a strong interaction effect with learning technique (Bostrom et al., 1990, Hollenbeck and Brief, 1987). However, the much broader concept of learning orientation, encompassing a comprehensive set of psychological factors (Martinez, 1999), still needs study. We postulate that learning orientation, similar to other cognitive abilities, will interact with the learning method. While different aptitude constructs are likely to have a different effect, we state the following proposition in general terms:

> **P7:** *Assuming that the learning method has well-designed structures, individual aptitudes will affect learning outcomes directly as well as indirectly by affecting the faithfulness of learning method appropriation.*

In summary, the various aptitude-treatment interaction studies cited above provide evidence for interactions between learning methods and individual aptitude and for the direct effects of individual aptitudes on learning outcomes (Kettanurak et al., 2001). We found no studies that explored the indirect effect of individual differences on learning outcomes through learning method appropriation. The direct effect is probably best explained through better content appropriation, while the indirect effect deals with process or learning method appropriation. We chose not to put a direct effect arrow in Figure 1 because our focus is on process appropriation. Any research on individual differences needs to investigate interaction, and direct and indirect effects. The model and arguments presented above provide a good framework for researchers to examine the effect of individual differences and validate the proposition stated above.

The proposition also provides an argument for personalizing training. The trend toward creating learning objects (LO) has made the possibility of personalizing training a reality. Learning objects are small electronic units of educational information that are flexible, reusable, customizable, interoperable, and easily retrievable. Personalization involves two issues: selecting the right LOs and then packaging LOs with appropriate context information to fit a given learner. This process presupposes a good understanding and application of aptitude-treatment interaction research. Personalization is a rich area of research in training as well as general learning systems.

5. Examples of Operationalization of the Model

The key component of the operationalizing of any conceptual model is to generate a contextualized and falsifiable set of hypotheses. The model outlined above can be operationalized in multiple ways depending on the interest of the researcher. Researchers can focus on the structures (spirit and learning methods) and/or the learning process (appropriation moves, scaffolds, and individual differences), while accounting for the other parts. However, in both cases, we look toward smaller, more focused theories to provide the magnitude and direction of the causality. We illustrate the operationalization of the model with two examples below, starting with the structural focus.

5.1.1. Structural or Variance Research Example

Only two studies that we know of have focused on technology structural dimensions (Gupta, 2008, Zhang et al., 2004). We use a study by Gupta (2008), which compared a web-based training tool method that had higher levels of enactive structural dimensions with a video training learning method for training students in Excel, to illustrate how this model can be applied to develop specific hypotheses from a structural focus. Figure 2 outlines the relationship between an underlyng theory, the manifested structural dimensions and technology-mediated learning tools.

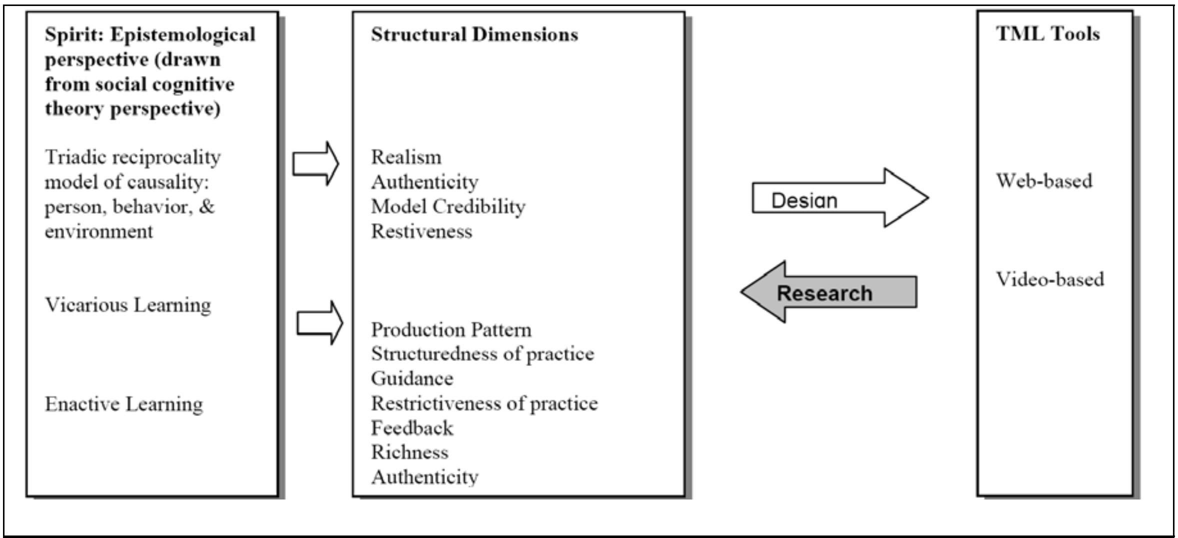

Figure 2: Relationship between Theory, Structural Dimensions and TML

The first step is to identify the underlying theory for a TML tool. Most learning-from-computer systems, used by most business and academic organizations, demonstrate actions (vicarious learning) followed by an opportunity to replicate the actions in a simulated setting (enactive learning). The underlying epistemological perspective is social cognitive theory (SCT). Figure 2 also shows the structural dimensions derived from this theory, which were discussed in Section 4.3.1.

Table 6 summarizes hypotheses that could be developed applying our TML model in Gupta's study context (2008). The learning goals/outcomes focused on were cognitive knowledge enhancement as well as increased learner satisfaction and self-efficacy. The first four hypotheses, which are based on the differences in the level of structural dimensions, test the effectiveness of the learning method. The last three deal with the learning process. The results for the four hypotheses actually tested in Gupta's study (2008) are shown in Table 6.

Table 6: Proposition - Hypothesis Mapping		
Propositions	***Actual / Examples of hypothesis***	***Test in Gupta et al. (Gupta)***
P1: Ceteris paribus, the more the structural dimensions of TML technology manifest empirically supported learning theory, the greater its effectiveness on learning outcomes.	H1: Individuals using the SCT based web-based technology (WBT) methods will perform better on learning outcomes (self-efficacy, cognitive knowledge outcomes & satisfaction) when compared to non-WBT methods	Supported for self-efficacy and cognitive knowledge
P2: Ceteris paribus, methods manifesting higher levels of the structural dimensions outlined in Table 4 will have greater effectiveness in terms of learning outcomes.	H2: Individuals using paired learning methods will perform better on learning outcomes (cognitive knowledge, self-efficacy, satisfaction) when compared to non-paired methods	Supported for self-efficacy and satisfaction
P3: Ceteris paribus, the more the structural dimensions of a learning technique manifest supported learning theory, the greater the technique's impact on learning outcomes.	H3: Individuals using the project based learning method will perform better on cognitive and meta-cognitive learning outcomes when compared to the reciprocal questioning method.	Not tested
P4: Learning method is a combination of various structures. Learning methods that display a consistent "spirit" across all structures will have greater effectiveness.	H4: Individuals in the combined learning method will show higher levels of learning outcomes (cognitive knowledge, self-efficacy, satisfaction) when compared to other methods.	Supported for all outcomes
P5: Participants appropriate learning method structures. Assuming that structures are well-designed, the greater the success of appropriation (faithful, attitude, and consensus), the greater the effectiveness of the learning method.	H5: The effectiveness of the learning method (technology-mediation, collaboration) on learning outcomes (cognitive knowledge, self-efficacy, and satisfaction) will be positively moderated by the level of faithfulness of appropriation.	Supported for all outcomes
P6: Assuming that the learning method has well-designed structures, process scaffolds influence the faithfulness of learning method appropriation.	H6: The use of wizards as a part of the learning process will improve the level of faithfulness of learning method appropriation.	Not tested
P7: Assuming that the learning method has well-designed structures, individual aptitudes will affect learning outcomes directly as well as indirectly by affecting the faithfulness of learning method appropriation.	H7: An individual's perception about his/her ability to use a TML tool will positively affect learning outcomes indirectly by positively affecting the faithfulness of learning method appropriation	Not tested

Other structural studies might focus on different learning methods based on different epistemological perspectives. These methods are likely to have different impacts on learning outcomes. Researchers could compare learning methods designed from two different perspectives, e.g., constructivist and cognitive, while keeping learning goals constant and controlling for other variables not of interest in the study.

5.1.2. Design Research Example

Propositions P1-P4 can also be operationalized to facilitate the design of a TML tool. In the Gupta study, the TML tool was selected because it included features that implemented enhanced enactive learning. Thus, it follows the research path in the Figure 2 map. As shown by the design arrow in Figure 3, this perspective can also be used by a design researcher or systems designer to build a new TML tool. The researcher would start by dimensionalizing the core components of a learning theory or theories and then implementing them in the TML tool.

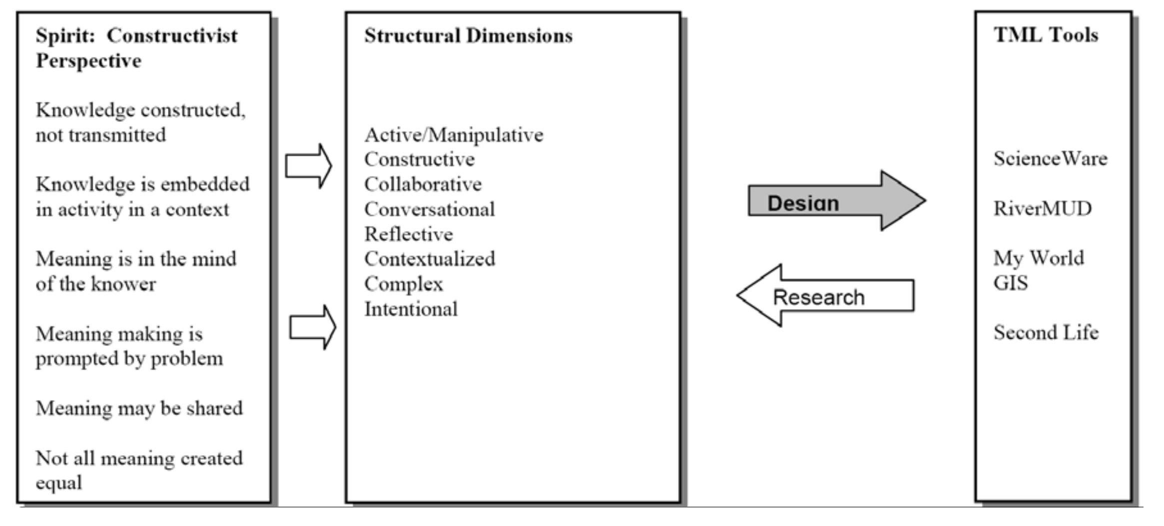

Figure 3: Relationship between Theory, Structural Dimensions and TML

Figure 3 illustrates a design research example in a constructivist learning environment. Jonassen et al. (1999) provides excellent examples of constructing TML tools based on a constructivist perspective. As presented earlier, the constructivist epistemological perspective states that individuals construct knowledge by working to solve realistic problems. The basic beliefs/assumptions of this perspective (Jonassen et al., 1999) for guiding the design and development of a TML constructivist learning environment are shown in the spirit box in Figure 3. Based on this perspective, Jonassen et al. (1999) outlined and operationalized eight dimensions for guiding the design and development of TML constructivist learning environments (see Figure 3).

The Jonassen et al. book (1999) describes a number of constructivist TML tools developed in the 1990s such as ScienceWare, RiverMUD, and Weather Visualizer. Early Virtual Worlds such as SimTown were also used in K-12 classes. Another example of a newer TML tool is My World GIS™. My World allows learners to explore and analyze geographic data about our world. Providing the learner with the ability to construct and manipulate models of real-world phenomena individually or in a group is at the heart of the constructivist approach (see dimensions in Figure 3). Currently, there is a lot of interest in Virtual Worlds such as Second Life in both IS (Ives and Junglas, 2008) and education (Aldrich, 2004). Most educational efforts are focused on K-12 and IS projects are focused on business training.

Once the TML tool is constructed, a researcher can use our TML model (See Figure 1) to guide researching the tool from a structural/learning method and/or process perspective. Learning method research would follow the procedure outlined above in the Gupta study.

A process study would focus on the appropriation process and learner moves/actions. Our AST-based model provides a framework and move categories (Poole and DeSanctis, 1992) but does not explain why certain moves are more likely than others or what influences the efficacy of these moves. When analyzing these, researchers need to draw on narrower process theories that focus on learners, their intentions, and individual expected outcomes on adoption or usage of TML tool. Theories from sociology, such as the theory of reasoned action or the theory of planned behavior, as well as IS theories of technology acceptance and diffusion, would fit this need.

6. Conclusion

Imparting knowledge has always been an important goal of academic institutions and industry alike. With the expanding role of technology-mediated learning (TML), designers/teachers are looking at using information technology as well as team-based learning methods to increase the effectiveness and efficiency of learning programs. However, as summarized in this paper, research in these areas suffers from limited and inconsistent results.

Table 7: How the Model will Support the TML Research Community
• Provides a comprehensive model for TML that can be used to integrate various theories for generating testable hypotheses. It provides a common framework for both variance and process researchers.
• Provides a framework for researchers, both in IS and Education, to summarize and integrate existing research and theories and identify research gaps to guide future research in this important area.
• Argues for a need to focus on the structural dimensions to get more consistent and generalizable results. Variance theories should be used to understand/predict the effects of learning method structures on outcomes.
• Outlines the concept of design "spirit," which governs the overall design of the learning method.
• States the guideline that researchers focusing on the structural aspect of the model need to control for process effects. Process researchers, on the other hand, need to account for the variance in structures in their analysis and discussion of results. Process theories can be used to understand/predict appropriation moves.
• Integrates the concept of reciprocal causation in terms of the interplay between learning method structures and actors/learners.
• Suggests that researchers focusing on scaffolds or individual differences should use the model to understand the effects of these variables on the learning process instead of only focusing on their effects on learning outcomes.

Table 7 outlines how the model presented will support the TML research community. First, the model has a global perspective that encompasses the important elements of the learning phenomenon and can be used to integrate many predictive, but narrower, IS and educational theories. For example, we showed how theories from educational psychology, such as social cognitive theory and social development theory, can be integrated into this framework. The model also embodies different existing IS TML frameworks including those presented by Sein et al. (1989), Alavi and Leidner (2001), Alavi and Dufner (2005), Fjermestad et al. (2005), and Sasidharan and Santhanam (2006).

A major strength of the model is that it allows researchers to emphasize either actors' influence on structures and/or structures' influence on actors (Poole and DeSanctis, 2003). When analyzing the impact of the structures, the model argues for a focus on structural dimensions. Such a focus would help ground the structures in theory and provide more generalizable and comparable results. The model also expands on how a learning method is designed. The model can be applied to both types of technology-mediated learning: learning-from-computers and learning-with-computers. The model operationalizes the concept of spirit in a TML context and its effect on building the structural potential of the learning method. The model also provides important guidelines for researchers, such as making sure to focusing account for the process effects in order to have a useable result.

The model also provides guidelines for researchers interested in the actor's actions. Process researchers need to account for the variance in structures in their analysis and discussion of the results. More importantly, the model provides a mechanism though which the researchers can understand the appropriation moves that the learners take. The concept of reciprocal causation, i.e., how the structural moves change the structural potential of the learning method, can also be researched using this model. Finally, researchers focusing on scaffolds or individual differences should use the model to understand the effects of these variables on the learning process instead of only focusing on their effects on learning outcomes.

Overall, this paper has developed a comprehensive research model and a set of research propositions to guide research in different TML contexts. The model also provides a method to summarize research into one nomological network, thereby providing a richer understanding of the TML phenomenon. By using this integrative theoretical model, researchers can also facilitate and dramatically accelerate cross-disciplinary and trans-disciplinary knowledge creation among the different disciplines focusing on TML: information systems, education, and computer science. We strongly encourage such collaborative efforts!

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Appendix 1: Definitions of Key Terms

Term	***Definition***	***Primary Section Discussed***
Learning Context	A collective set of environmental elements that enable or constrain learning.	4.1
Structures	Structures are rules, resources and capabilities embedded in a context	4.1
Spirit	Spirit outlines the goals, values and assumptions about knowledge that influence the design of the learning method.	4.2
Learning goals	The desired knowledge to be attained as a result of the learning/training process.	4.2.1
Learning outcomes	The learning outcomes represent the goal assessment or measures for determining the accomplishment of learning goals	4.2.1
Epistemological perspective	Overarching beliefs about the nature of knowledge and about what it means to “know” something	4.2.2
Learning Method	A learning method is defined as a combination of structures that guides individuals to achieve the learning outcomes	4.3
Structural features	Structural features are the specific capabilities offered by structure	4.3
Structural dimensions	Structural dimension describes a scalable characteristic of structure or set of structures	4.3
Learning Process	The learning process outlines the participants actions regarding learning and adapting the learning method structures based on their interpretation of the spirit	4.4
Appropriation	It is the process where participants learn and adapt the structures based on their interpretation of the spirit. Faithful appropriation occurs when participants’ interaction is consistent with the spirit	4.4
Appropriation moves	Appropriation moves describe the ways in which learners adapt structures to accomplish learning goals.	4.5
Process Scaffold	A scaffold provides initial assistance to support the learning process. This is also referred to as appropriation support.	4.5.1
Individual Aptitude	Aptitudes are the initial states and abilities of persons that influence behavior, given specific conditions	4.6

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