MANAGING INFORMATION SYSTEMS DEVELOPMENT PROJECTS: WHAT'S ON YOUR MIND

Research-in-Progress

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Abstract

Drawing on a mental model perspective, we investigate information systems (IS) project members' knowledge and beliefs about how to manage information systems development (ISD) projects. A new construct – ISD mental models – is proposed and defined as the knowledge and belief structures that help IS project members to understand, conduct, and manage ISD projects. Literature reviews and cognitive interviews using the repertory grid technique are used to identify the fundamental concepts that are in project members' mental models. This study further proposes that the structure of mental models is organized into four ISD project-related areas: product, process, people, and organization. This proposition will be tested by a survey with ISD project members using the pairwise comparison technique. Expected contributions and implications are discussed.

Keywords: Cognition, Mental Models, ISD Methodologies, ISD Project Management

Introduction

One of the fundamental information systems (IS) project management issues inherent to both practice and academia emanates from the need to know what knowledge project members must possess and what different beliefs project members hold. Without appropriate and sufficient knowledge, project teams cannot react to changes in requirements and technologies (Kensing and Munk-Madsen 1993; Naur 1985). Without an appropriate understanding of the beliefs of fellow team members, project members are apt to propose work practices and make decisions that are technically, politically, or otherwise unacceptable to other people, thereby reducing the synergistic potential of diverse expertise and creating confusion and conflict (Huber and Lewis 2010). For example, two IS project management schools rely on different knowledge and have different beliefs (e.g., Naur and Randell 1969): the Process school (e.g., Waterfall, CMMI, and PMBOK) and the People school (e.g., Agile). The proponents of the former argue that careful upfront design, meticulous top-down planning, and rigorous quality control reduce risks of a runaway project. Advocates of the People school emphasize a need to capitalize on each individual's strength, including both development teams and customers, to meet highly volatile, ambiguous, and uncertain requirements (Highsmith 1999). While both schools demonstrate some successful anecdotal stories, in reality, the efforts to doctrinally implement work practices underlying each school do not often come to fruition for organizations. Apparently, there is no one-size-fit-all solution. However, people often adopt habitual ways of solving problems (Glass 2003). An incomplete understanding and biased beliefs about how to tackle organizational uncertainties, technological complexities, project requirements, team dynamics, and processes likely adversely affect many decisions made in an ISD project. To improve collaboration and coordination between project members, this study aims to explore project members' minds about ISD project management.

We adopt a cognition perspective via a mental model approach. Taking a cognition perspective has the potential to allow us to holistically understand the multiple aspects of ISD projects. Substantial research has already been devoted to understanding technological, organizational, project, task, team, people, and process factors for better addressing project effectiveness (Aladwani 2002). Although these factors – individually or partially combined - have demonstrated their influence on IS project outcomes, little research has adopted an integrative perspective.

Mental models[1] are of particular value to understanding cognitive processes because cognitive processes rely on past experience stored in memory. Such experience is presented as knowledge and belief structures in mental models (Mohammed et al. 2010; Rouse et al. 1992). While the mental model research related to IS projects is limited, research in other contexts demonstrates that sound, well-connected mental models enhance effective decision-making and collaboration of complex tasks. For example, prior research has shown that accurate mental models positively affect decision outcomes in different contexts, such as military combat teams (Lim and Klein 2006), air traffic control (Smith-Jentsch et al. 2005), nuclear plant operations (Waller et al. 2004), and strategic investment issues in banks (Hodgkinson et al. 1999). Current IS research pays attention to mental models about the design and development of IS, such as programing (Cooke and Schvaneveldt 1988; Lau and Yuen 2010; Shaft et al. 2008), system analysis (Kudikyala and Vaughn 2005), conceptual modeling (Siau and Tan 2005), and maintenance (Shaft and Vessey 2006). These studies have demonstrated ways of improving design and development activities in light of understanding the mental models of experts and novices. While this mental model shows the potential to advance project members' competencies, it is insufficient for fully understanding the impact of project members' mental models on project effectiveness. What is missing is a more systematic and integrative perspective on managing people, product, and processes in an ISD project. We attempt to address this need in our research.

To understand the impact of mental models on ISD projects, this study proposes a new construct, an ISD mental model, and defines it as the knowledge and belief structures that help a project member to understand, conduct, and manage information systems development projects. The knowledge of interest

[1] A mental model is an individual's organized knowledge structure, which helps one to explain, understand, and predict events occurring in the environment (Rouse et al., 1986). A variety of terms have been used, such as mental representations, cognitive structures, cognitive maps, knowledge structures, and schemas.

in an ISD mental model is ISD process knowledge: the knowledge of how to manage, control, and implement ISD (Iivari et al. 2004). Unlike other types of knowledge that focus on individual tasks (e.g., technology knowledge, application domain knowledge, and organizational knowledge), ISD process knowledge considers knowledge across different aspects of ISD (e.g., task, people, technology, and organizations) and different phases of a project (e.g., planning, analysis, design, and implementation). Such knowledge concerns people, process, and product aspects of IS projects and contributes to creativity, productivity, and quality (Cohn 2010). We posit that ISD mental models should act as an important guide for project members to address problems occurring in ISD projects.

We acknowledge that in addition to cognitive factors, there are other contextual factors affecting ISD project effectiveness (e.g., socio-political, organization, and task factors). What we propose is that a mental model is fundamental to a human's behavior and that it guides actions in response to different project constraints and contingencies. Insight should be gained into project effectiveness by understanding one's mental model. People are the only agents who can initiate interactions and make changes. To shift one's mental models to more well developed ones, we have to first possess a sophisticated understanding of what the ISD mental model is.

Although some efforts have been made to understand what critical knowledge IS project members should have (Iivari et al. 2004; Lee et al. 1995), questions arise as to how such critical knowledge is interpreted by project members, what essential concepts are being abstracted and then coded in mental models, and what relationships exist between these concepts. A more complete understanding is needed via carefully categorizing ISD process knowledge into fundamental concepts of project members' mental models. We summarize our research question below and then offer preliminary propositions to guide the empirical work.

What is an ISD mental model in terms of the major ISD concepts comprising a project member's knowledge, his/her belief structures and how these concepts interrelate?

What is an ISD Mental Model?

The term mental model has been commonly used in everyday communication. Research in different disciplines has pushed the mental model from a metaphor toward a construct with greater clarity and more precise measurement (Klimoski and Mohammed 1994). Yet, recent literature review laments that the current usage of mental models is still too generic and there is a lack of research in specifying mental models in particular contexts (Mohammed et al. 2010). Little is known about what specified knowledge and beliefs resides in a human's mind for different problem domains. Our research addresses the call by attempting to open a black box of ISD project members' minds. Project members are confronted with a variety of problems and tasks from planning, analysis, design, to construction. Project members can be perplexed about things such as why many important details emerge later in the process, what users really want for their information systems, and how system design should respond to changing requirements within budget and schedule. In such an uncertain work environment, project members have to tackle the above issues based on the repertoire of knowledge at their disposal and use preferred work practices to solve problems. We refer to the repertoire of knowledge as well as its underlying assumptions and beliefs as an ISD mental model. Specifically, we define it as the knowledge and belief structures that help a project member to understand, conduct, and manage information systems development projects

Our research draws on the deep literature and tools/techniques developed over several decades of research in cognitive psychology. To define a mental model, the content and structure has to be examined. The basic element of the content of a mental model is a concept - a meaningful unit in memory - and is composed of a class of objects/instances that share similar characteristics and belong together (Smith 1990). Concepts about managing ISD can be distilled from a variety of technical and managerial practices and solutions for ISD and then be combined into a map of project member's mental model. The relationships among these ISD concepts define the structure of an ISD mental model (see Figure 1 for an example). Interrelationships between ISD concepts are gradually shaped from learning, training, interaction with other stakeholders, and project experience. Project members therefore develop implicit theories for understanding and managing ISD (Naur 1985). The structure affects expectations and actions. For example, a project member could have a strong belief that strict control over developers and users (a concept, which possibly includes a set of instances or work practices, where daily job journals and

detailed meeting minutes are required) is essential to scope and schedule management (another concept). The whole statement presents an implicit theory; project members who hold such concepts and an implicit theory prefer and may perform projects with tight supervision. Given little current knowledge around the content and structure of ISD mental models, we will discuss potential sources and organizations of mental models based on theoretical understanding of ISD and mental models.

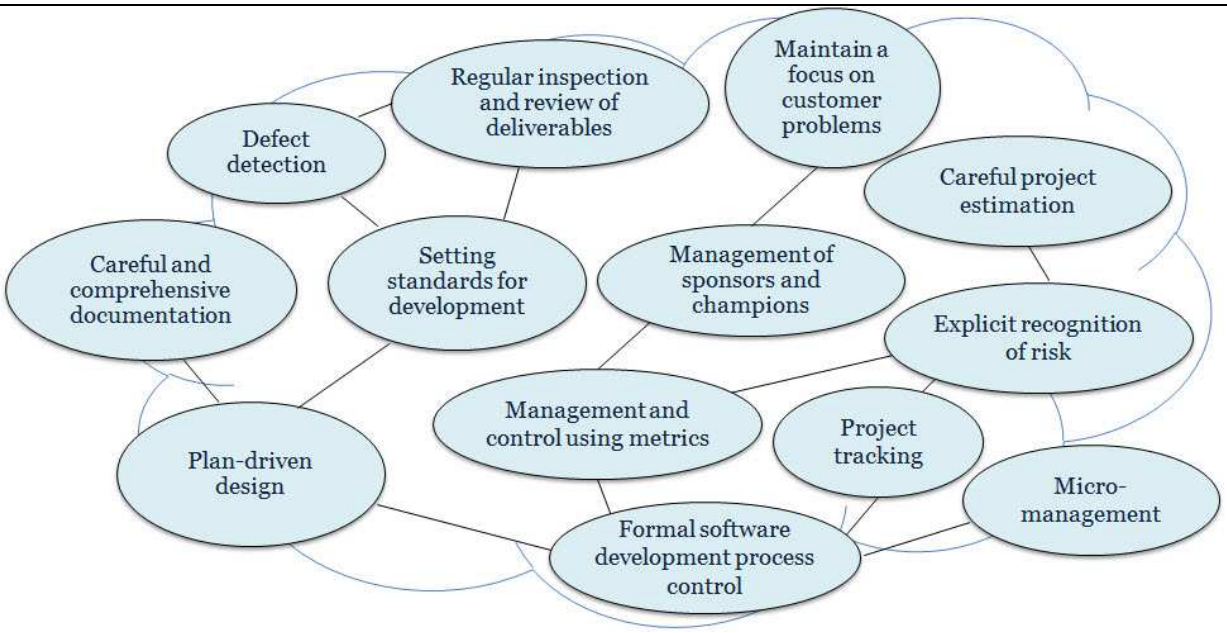

Figure 1. An Example of an ISD Mental Model

Content of ISD Mental Models

Concepts are the building blocks of a mental model (Kunda 1999). Our study is looking for fundamental concepts - an abstract notion of knowledge about managing ISD projects – in ISD mental models. Different from work practices -"real" ways of doing things (Iivari and Iivari 2011), the fundamental concepts are more powerful to understand decision-making and behaviors than work practices (or subordinate concepts) because they are more static (Armstrong and Hardgrave 2007) and represent the essential spirit of work practices. For example, focusing on people and collaboration during development is a fundamental concept of the Agile approach. XP's pair programing or Scrum's working in a common project room are only one of many ways to substantiate the concept. People may develop their understanding of concepts as they continuously conduct these work practices and this shapes a person's mental model (Kensing and Munk-Madsen 1993).

We suggest that ISD methodologies[2], including software engineering oriented and project management oriented methods, should serve as a starting point to identify fundamental concepts. Methodologies are made up of accumulated work practices based on IS experts' experiences (Avison and Fitzgerald 2007). Different methodologies thus can comprehensively capture a variety of work practices. Also, many of methodologies systematically organize work practices into more abstract knowledge, which summarize fundamental concepts. It is therefore appropriate to define a pool of fundamental concepts from ISD methodologies. Furthermore, both academia and practitioners keep searching for the methodological holy grail because they believe that the "right methodology" will set right directions and rules of action, resulting in productivity and quality gains. The pursuit of methodologies in IS communities shape mindsets of IS professionals to a certain extent through training, communication, socialization, and institutionalization. Work practices that effectively facilitate project implementation and fits personal

[2] An ISD methodology contains "a collection of procedures, techniques, tools, and documentation aids which will help the system developers in their efforts to implement a new information system" (Avison and Fitzgerald 2007).

values and goals then turn into salient fundamental concepts represented in individuals' mental models. Our goal is to identify fundamental concepts across ISD methodologies. We propose to understand fundamental concepts from the principles of methodologies and to summarize principles from work practices of methodologies. Then, the concepts will be validated by examining experts' mental models using mental model elicitation techniques.

Some people may express concern about the potential complexity and multidimensionality of the ISD mental model construct given a plethora of accumulated ISD knowledge. However, we believe that we can find balance between comprehensiveness and parsimony. We maintain that there are a finite number of concepts within mental models because knowledge is simplified and categorized according to the hierarchical principle of cognitive psychology. Supporting this, our current coding of books, papers, and methodologies (see the research methodology section), has found considerable overlap in the concepts. In sum, it is our suggestion that concepts elicited from ISD approaches and methodologies should be an approximation to the content domains of a project member's mental model. We propose the following.

Proposition 1: Fundamental concepts derived from ISD methodologies approximate the content of ISD mental models.

Structure of ISD Mental Models

Structure refers to the systematic arrangement of concepts within a mental model. The arrangement of concepts in mental models determines how a project member absorbs new concepts, makes an inference, and acts upon concepts retrieved in a particular context.

To understand the structure of mental models, we draw on category learning literature and propose that we could learn how and why certain salient concepts interrelate in light of goals. Goals guide how specific concepts are given attention, encoded, and organized (Barsalou 1991). Four major types of goals characterize ISD: product-oriented, process-oriented, people-oriented, and organization-oriented. For example, one of the major goals belonging to the product-oriented dimension is to produce a reliable, adaptable software product with high quality. In order to ensure achieving product-oriented goals, practical and technical activities have been advocated, including analyzing organizational contexts and technical options, formulating a blueprint for a desired change in an organization, and finally implementing a system. Simply speaking, analysis, design, and realization are three primary activities to ensure functioning software (Andersen et al. 1990). Constant refactoring to improve code quality can illustrate one of product-oriented work practices and be categorized into the "promote simplicity" and "pay continuous attention to technical excellence" concept at the abstract level. The goal is to create better software that is easier to maintain. Concepts with product-oriented goals are more likely to be formed in project members who have experience in system construction such as programmers, system/business analysts, and system business architects.

In comparison to the product-oriented goals, the process-oriented goals help a project to meet constraints – cost, schedule, and scope. Process-oriented work practices attempt to answer questions such as where/how is a project/task going, where are we, what are potential obstacles on the way. Planning, evaluation, and regulation are three primary activities to keep a project on track (Andersen et al., 1990). For instance, estimation of software development efforts is a part of planning and is intended to identify scope, schedule, and budget. Via either informal (e.g., expert judgment) or formal work practices (e.g., work breakdown structure, function point analysis, COCOMO, XP's planning games), a project can be assessed and evaluated. Further, development efforts can be monitored and managed. Project members whose responsibility is project management, such as project managers and IT/business managers, may have more salient concepts concerning the process.

The people-oriented goals concern a project member's well-being, interpersonal relationships, and productivity in a project. Focus is on work practices such as performance measurement, work arrangements, and training (Agarwal and Ferratt 2002). The people-oriented work practices involve more cognitive, affective, and social elements. Project members, regardless of supervisors or subordinate, should all have knowledge and beliefs about how people should be managed and treated in projects. Some project members may prefer empowerment, open workspace, mentor-based training, teamwork, and flexible work/time arrangement. Others may be more inclined to delineation of authority, performance

appraisal on individual outcomes, and strict control of project members' behaviors. Empirical research has implicitly shown different beliefs regarding the people-oriented work practices such as training needs (Jiang et al. 2000; Nelson 1991), team development, and leadership (Jiang et al. 2000).

Unlike achieving technical excellence through product-oriented practices and meeting time, budget, and scope through process-oriented practices, organizational-oriented goals focus on delivering value to customers and increase return on investment (Basten et al. 2011; Pinto and Mantel Jr 1990). Organization-oriented work practices consider the impacts external to projects and are set to satisfy external project stakeholders (e.g., users and customers) and help their organizations attain competitive differentiation. For instance, the "short development cycle with frequent releases" concept meet the time to market needs of customers and help customers outpace the competition.

Project members, consciously or unconsciously, pursue these goals to meet needs for personal advancement and growth, peer recognition, and work requirements (Haslam et al. 2000). Over time, the application of certain concepts becomes habitual and certain concepts become chronically accessible altogether (Fishbach and Ferguson 1996). We suggest that the product-oriented, process-oriented, people-oriented, organization-oriented dimension of ISD embody the four primary types of goals about ISD activities. Concepts in mental models will be relevant to these types of goals. It is important to recognize that we do not propose that there is a clear-cut knowledge structure based on these four types of goals (i.e., concepts can only be categorized into single type of goal) but propose that there are patterns across one's knowledge structure – some concepts are more likely to interrelate due to their dominating goals. The four types of goals should be able to inform a better understanding of ISD mental models. It is likely that experienced project members are equipped with a well-developed knowledge structure with concepts across four goals. The empirical findings could help us gain insight regarding how experts link different concepts and how project effectiveness should be enhanced. The proposition below serves as an exploratory step and theoretical lens to understand mental models.

Proposition 2: ISD concepts with the similar ISD goals should be grouped together in the structure of ISD mental models. Specifically, ISD concepts should be classified into four types of ISD goals: product, process, people, and organization

Research Methodology

Precisely measuring and representing complicated mental models has long been a challenge for both academia and practitioners (Langan-Fox et al. 2000; Mohammed et al. 2010; Smith-Jentsch 2009) due to the multifaceted nature of mental models. As explained above, content and structure are the two primary aspects of mental models in any given problem domain. Content refers to an individual's knowledge and beliefs for a domain while structure presents the organization of that knowledge and beliefs. Only when the content of mental model is properly defined and structure is adequately captured, can a highly valid mental model construct be achieved and the relationships between the mental model and other constructs in its nomological network be meaningful examined (DeChurch and Mesmer-Magnus 2010; Suddaby 2010). From the methodological point of view, elicitation and representation are two major underpinnings of studying content and structure of mental models. Elicitation refers to the technique used to "determine the components or content of a mental model"; Representation refers to the technique used to "reveal the structure of data or determine the relationships between elements in an individual's mind" (Mohammed et al. 2000). We will adopt the repertory grid technique (RGT) with ISD experts complementary to the content analysis of ISD methodologies to elicit concepts; we will rely on the pairwise comparison technique and multidimensional scaling technique to represent mental models.

Content Analysis

We started with distilling concepts from ISD methodologies suggested by Iivari et al. (1998) and Iivari et al. (2000) and extended our search and analysis to any relevant ISD methodologies not included in Iivari et al.'s (1991; 1998, 2000; 2004) papers. The content analysis covered popular textbooks on system analysis and design (Kendall and Kendall 2004; Whitten and Bentley 2006), software engineering (Glass 2003; Sommerville 2004), IS project management (Highsmith 2009; Murch 2001; Olson 2001), and practitioner's books on ISD methodologies (Avison and Fitzgerald 2007). We also reviewed seminal

papers about agile development approach (Abrahamsson et al. 2010; Abrahamsson et al. 2003; Highsmith 1999; Williams 2010) with associated methods such as XP (Beck 2000), Scrum (Schwaber and Beedle 2001), and Crystal (Cockburn 2005). We focused on fundamental concepts of current ISD practices and extracted 33 fundamental ISD concepts with over 70 subordinate concepts and practices (see Table 1 for examples). The fundamental ISD concept is a relatively abstract concept, such as careful project planning and scheduling, while the subordinate concept and practice is a more concrete concept, such as function point analysis and work breakdown structure. Concrete concepts facilitate an understanding of abstract concepts (Kensing and Munk-Madsen 1993; Medin et al. 2000). We posit that our literature review establishes a theoretical framework for understanding what potential ISD concepts within project members' minds would be. The next step, described below, will be to conduct in-depth interviews with ISD experts to determine the comprehensiveness of the framework and that theoretical saturation has been reached.

Table 1. Examples of ISD Concepts

Fundamental Concepts	Subordinate Concepts	Goal
Focus on collaboration and communication during development	e.g., pair programming, working in a common project room, getting the programmer together with the person who has the problem, face-to-face communication.	product
Project monitoring and tracking	e.g., using "earned value" project tracking to monitor project progress, daily stand-up meetings.	process
Developing capabilities	e.g., training, the identification of core competencies needed for projects.	people
Shorter development cycles with frequent releases	e.g., automatic build and testing to ensure quality of new releases.	organization, product, and process

The Repertory Grid Technique

We will conduct interviews with the repertory grid technique (RGT) because of its high validity and test-retest reliability (Wright 2008) and its appropriateness for addressing our research questions. The RGT can go deep into an individual's knowledge and belief structure via iteratively asking the participant to differentiate concepts in a given domain (Langan-Fox et al. 2000). For more information about the RGT, see Tan and Hunter (2002), Curtis et al. (2008), and Edwards et al. (2009). Below we describe the application of the RGT in eliciting ISD concepts from an ISD expert's mental model.

Our subjects will be ISD experts who have rich experience in ISD projects. The job roles include senior management, project managers, business/system architect, business/system analysts, programmers, and testers. We plan to recruit 15-25 ISD experts and believe the point of saturation or point of redundancy will be achieved (Tan and Hunter 2002).

During the RGT interviews, the participant will be asked to identify six IS projects he/she had worked. Then, we will put the six projects on index cards and add two cards to the stack as anchors, with one labeled "ideal" and one labeled "unsuccessful". The two pseudo labels not only increase the contrast between projects but also help the researcher understand attitudes and beliefs about extreme cases in the participant's mind. The participant will begin with shuffling the deck of eight index cards and randomly select three index cards from the stack. Then the participant will be asked: "Tell me in what important ways two of these three projects are the same, but different from the third, in terms of important managerial and technical practices for developing an information system in a project setting." We will encourage the participant to think of the contrast (e.g., incremental development vs. linear development) rather than the negative (e.g., incremental development vs. non-incremental development) because the negative word provides little information about in what way two concepts are different (e.g., what does "non-incremental" mean?). The result of their answers will be a pair of words or phrases used to describe both the similarity and the contrast. Different combinations of three projects will be presented and the average triad to reach saturation is between 7 and 10 (Reger 1990).

At the end of each interview, we will ask the participant to confirm the concepts generated in the interview and verify if the concepts exactly present their knowledge and beliefs about managing product, people, and processes in a project team. The participant can add or remove the elicited concepts. Also, the researcher can assist the participant in refining the elicited concepts via the laddering technique if the elicited concepts are still too vague or too specific.

The number of raw concepts elicited may be daunting. However, it is possible to reduce the number of raw concepts since concepts can be organized in hierarchies, with more abstract concepts at higher levels and more specific concepts at bottom levels (Kelly 1955; Kunda 1999). Lower level concepts inherit attributes, characteristics, principles, and core values from higher level concepts. The hierarchy of mental models makes our world manageable. To further clarify the ISD mental model and for following comparison and analysis, it is important to make the terms with similar/identical meanings consistent and classify the raw constructs into an appropriate level. This study will follow the open coding technique (Strauss and Corbin 1990) by comparing and contrasting raw concepts based on concepts generated by participants and interview notes. The raw concepts will be grouped into higher level concepts when they share the same properties. In order to check inter-rater reliability, multiple coders with ISD expertise will get involved in the open coding process. To support proposition 1, the results can be compared with concepts coded from ISD methodologies. The discrepancy between these two sources illustrates to what extent project members' concepts match those from ISD methodologies.

Pairwise Comparison and Multidimensional Scaling Analysis

To address proposition 2, we will use the pool of concepts developed previously and conduct a survey of IS project members to capture the underlying structure of ISD mental models using the pairwise comparison technique (Langan-Fox et al. 2000). We will present respondents with a list of concepts with definitions and accompanying work practices and ask respondents to describe the relationships among the concepts on a 7-point scale from -3 to +3, where -3 denotes a very strong negative relatedness and +3 denotes a very strong positive relatedness. Zero denotes that no relationship is perceived to exist between the concepts in question. The results will be compared and analyzed by the multidimensional scaling technique in order to gain a deeper understanding of the underlying dimensions of concepts and the interrelationships among concepts. Spatial configurations of concepts will be drawn. Similar concepts will group together while different concepts fall into other dimensions. The greater the difference between concepts, the greater the distance between them in the spatial configuration. We expect to find four dimensions: people, product, process and organization.

Expected Contributions

This study will make novel contributions to the IS literature and practice by leveraging a cognitive lens to comprehend how project members construe ISD project management and what/how fundamental concepts are formed and organized. We are identifying concepts that have emerged across the different ISD methodologies and that are elicited from ISD experts. We believe that the result will be a rigorously defined mental model for ISD project management. We also argue that the ISD mental model construct should be a useful starting point for developing a systematic, theory-based study of different ISD problems. For example, research on project management can build upon the ISD mental model and explore the role of mental models in conflict. We suggest examining how destructive conflict can be avoided and constructive conflict can be promoted can be done by assessing to what extent mental models should be compatible and what fundamental concepts should be shared. Understanding compatible mental models (i.e., where the underlying goals and values in project members' mental models are not in conflict) will help explain why some differences are irreconcilable and why task conflict often turns into relationship conflict. Understanding which fundamental concepts need to be shared among project members could allow a team to create an environment for constructive discussion where members can begin their conversations with other members on common ground. The ISD mental model construct could also help to examine the fit between methodologies and organizational members' mental models. Understanding this would allow organizations to tailor methodologies to fit majority of mental models or provide training to reducing cognitive gaps of individual members. Since introducing methodologies into

organizations continues to be challenging, a deeper understanding of how to do this successfully would be valuable.

From a methodological point of view, the ISD mental model will be valuable to identify actual similarities and differences between individuals in dyads, teams, and organizations via integrating the RGT and a pairwise comparison technique. The need to diagnose and manage different knowledge and beliefs is growing in importance partly because of an increasing need to merge and mold different expertise as organizational changes have occurred (e.g., when different organizations and units merge) or new projects are composed of members who have diverse backgrounds.

In practice, Humphrey (1999), known as the "Father of Software Quality", indicates that "since they [software engineers] are given little or no professional guidance on how to do the work, most engineers start off with exceedingly poor personal practices". We posit the ISD mental model construct may help to provide parsimony and order to the diverse set of technical and managerial practices. People are generally unaware of their mental models until they are challenged, until they experience new concepts and work practices, or until the mental model is made overt and explicit through a theoretical framework (as we plan to develop in this study). Future research can draw on the ISD mental model construct and examine "ideal" content and structure for different types of IS projects. We will learn what essential concepts are needed and which ISD concepts are complementary to each other. From the organizational point of view, quite a few organizations attempt to combine concepts and practices from either the Process school or the People school to suit the unique needs of their environment. This research will develop procedures that will permit organizations to identify their existing team/organizational capabilities regarding how best to manage ISD projects, processes, and personnel and to create a portfolio of ISD work practices that best fit their unique organization.

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