KNOWLEDGE MANAGEMENT SYSTEM USE AND KNOWLEDGE ACQUISITION:

SOME INITIAL EVIDENCE

Dissertation Proposal

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Abstract

In an effort to harness knowledge within an entire firm and distribute it throughout, many firms, including the "Big Four" accounting firms, have implemented knowledge management systems (KMS). Concerns have been raised, however, about the potential dependency of users on KMS and the related decrease in knowledge acquisition and expertise development (O'Leary 2002b; McCall et al. 2005). The purpose of this study is to investigate the impact of KMS use on interpretive problem solving skills, declarative knowledge acquisition, and procedural knowledge acquisition, focusing more specifically on procedural knowledge. In addition, the study examines the specific separate effects of examples and rules embedded in a KMS on interpretive problem solving skill improvement, declarative knowledge acquisition, and procedural knowledge acquisition.

The study uses an experimental methodology to investigate the effects of KMS use on knowledge acquisition. In the first experiment, KMS use and traditional material use are compared. Specifically, the improvement of interpretive problem solving skills, declarative knowledge acquisition, and procedural knowledge acquisition are investigated to determine whether there is a difference between KMS users and traditional material users. This research posits that users of traditional materials acquire more declarative and procedural knowledge, while the KMS users exhibit more improvement in their interpretive problem solving skills. In the second experiment, the knowledge acquisition of users of KMS embedded only with rules is compared to that of users of KMS embedded only with examples. Specifically, the interpretive problem solving skills improvement, declarative knowledge acquisition, and procedural knowledge acquisition are analyzed to determine whether such acquisition differs between users of KMS. This research posits that users of KMS embedded with rules acquire more declarative and procedural knowledge, while the users of KMS embedded with examples exhibit a greater improvement in interpretive problem solving skills. This study provides implications for KMS development and use and contributes to the intelligent decision aid literature.

INTRODUCTION

"Knowledge is power" (Cameron 2000) and is quickly becoming an organization's key asset. Recognizing the importance of knowledge, the psychology literature has long promoted knowledge as a key determinant of performance (Anderson 1985; Campbell 1990; Campbell et al. 1992; McCloy et al. 1994; Kanfer & Ackerman 1989). Research in accounting indicates that knowledge is an indicator of accounting judgment and decision-making performance (Bonner et al. 1997; Libby 1995; Libby & Luft 1993; Roberts & Ashton 2003; Roberts & Dillard-Eggers 2005; Bonner & Pennington 1991). Procedural knowledge (i.e. knowledge used to solve problems by applying factual knowledge), in particular, is fundametnal to the development of expertise (Herz & Schultz 1999).

At the organizational level, keeping valuable knowledge in-house is critical to sustaining a competitive advantage. The literature documents that knoweldge acquisition is a costly process (Earley 2001), and once knowledge is obtained, competitive advantage relies on sustenance of such knowledge. Furthermore, retaining knowledge within the organization has long been a dilemma in public accounting firms as employee turnover is problematic (Taylor & Cosenza 1998). Knowledge possessed by an individual is retained by that individual and taken with him/her to his/her new position.

In an effort to harness knowledge within an entire firm and retain and distribute it throughout, all of the "Big Four" accounting firms have implemented knowledge management systems (KMS) (Leech & Sutton 2002). This trend is not limited to the accounting industry. Other organizations have also adopted KMS, including powerhouses such as Ford and government bodies such as the SEC. KMS are knowledge based technologies that support and improve the management of knowledge, including processes such as knowledge creation, storage/retrieval, transfer, and application (Alavi & Leidner 2001). In other words, a KMS is a repository of knowledge from a collection of experts, organized in a manner such that it can be easily accessed. Importantly, the easy accessibility of this knowledge allows an individual near immediate access to knowledge that is relevant for the decision making task at hand. On the other hand, individuals accessing traditional materials, such as manuals, textbooks, and trade journals, are left to sort through multiple sources to obtain the relevant knowledge to use in decision making.

This widespread adoption has sparked concern by researchers that little is known about the actual benefits and potential detriments of KMS use (O'Leary 2002b). In fact, some predict that knowledge-based technologies may create over-reliance (Arnold & Sutton 1998) and that KMS use in particular may lead to a dwindling of expertise within the firm (O'Leary 2002b). Prior research has not addressed whether the knowledge transfer, expected from the use of a KMS, actually occurs (Alavi & Leidner 2001; Grover & Davenport 2001). Although organizations have adopted KMS in hopes to spread knowledge throughout the firm and ultimately improve performance, the potential lack of knowledge transfer may have the opposite effect. Knowledge determines performance and if an individual does not possess knowledge, but relies on technology to provide such knowledge, that individual will not have the knowledge to intelligently converse with clients, solve problems when the technology is unavailable, or develop future knowledge.

The purpose of this study is to investigate the impact of KMS use on knowledge acquisition. Specifically, this study investigates whether the use of KMS affects declarative knowledge acquisition, procedural knowledge acquisition, and interpretive problem solving. Furthermore, this study also examines the individual impacts of specific KMS components (i.e., examples and rules) on declarative knowledge acquisition, procedural knowledge acquisition, and interpretive problem solving. Declarative knowledge is knowledge of facts, while procedural knowledge is knowledge of how to apply these facts in solving problems (Anderson 1976). Interpretive problem solving is solving problems by means of analogizing from previously encountered examples (Anderson 1993).

This study will contribute to the accounting information systems literature by examining whether the concerns regarding the over-reliance on KMS and resultant hindrance of knowledge acquisition[1] are valid. Specifically, if KMS do impede knowledge acquisition, and the firms that implement KMS do not mitigate this effect, the long-term epistemological effects could be

[1] Knowledge acquisition refers to both declarative and procedural knowledge acquisition unless otherwise noted.

devastating. Acquiring requisite knowledge within a field is critical, if the field is to persist and further develop. The current study also extends prior literature regarding the impact of intelligent decision aids[2] on knowledge acquisition. The intelligent decision aid literature has been somewhat mixed as to whether intelligent decision aids increase (Eining & Dorr 1991; Fedorowicz et al. 1992), hinder (Brody et al. 2003; Glover et al. 1997), or have no effect (Steinbart & Accola 1994) on knowledge acquisition. Although the extant knowledge based technology literature has not specifically addressed the impact of KMS on knowledge acquisition, prior intelligent decision aid research does provide speculation.

The remainder of this paper is organized as follows. The next section discusses the prior literature. The following section discusses the theory and hypotheses. The final two sections discuss the methods used and the conclusion.

PRIOR LITERATURE

This study focuses on the impact of KMS use on knowledge acquisition in an accounting setting and as such, the study draws on prior literature related to intelligent decision aids and the resultant knowledge acquisition and accounting research addressing the knowledge acquisition process. The extant intelligent decision aid literature has examined a multitude of intelligent decision aids, with varying manipulations, and their impact on knowledge acquisition, providing speculation regarding the impacts of KMS use. The extant behavioral accounting literature has confirmed that experience affects knowledge acquisition, and in fact has cited implications for KMS use (Roberts & Dillard-Eggers 2005).

Knowledge is defined as "a justified true belief that increases an entity's capacity for effective action" (Nonaka 1994). Knowledge management refers to identifying and leveraging the entire body of knowledge of an organization to obtain a competitive advantage and entails creation, storage/retrieval, transfer, and application of knowledge. KMS are systems used to facilitate

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[2] Intelligent decision aids refers to all information systems that assist in decision making; it encompasses expert systems, decision aids, intelligent support systems, decision support systems, artificial intelligence systems, and executive support systems.

knowledge management and as such are defined as knowledge based technologies used to support and improve the knowledge management processes of knowledge creation, storage/retrieval, transfer, and application (Alavi & Leidner 2001). Importantly, these systems offer near immediate access to relevant knowledge to be used in decision making. KMS eliminate the costly search for relevant knowledge through various sources required when referencing traditional materials.

Alavi & Leidner (2001) identify three major types of KMS: (1) best practices, (2) corporate knowledge directories, and (3) knowledge networks. O'Leary (2002b) identifies and defines various KMS database components as News, Who Knows Who, Industry Intelligence, Internal Expertise, Human Resource-based Employee, Frequently Asked Questions, Lessons Learned, Proposal and Engagement, Best Practice, and Functional Knowledge databases (O'Leary 2002b). Best Practices databases and Lessons Learned databases both provide documentation of previous client problems and solutions (i.e. examples), while Frequently Asked Questions databases and Functional Knowledge databases provide definitions and rules to be used in client consulting and problem solutions. While KMS have been widely adopted and implemented in public accounting as well as all aspects of business, the effects of these systems, as well as the specific KMS components - examples, rules, and definitions – on knowledge acquisition are unexplored. Many authors have speculated that the use of these systems could hinder the knowledge acquisition process and lead to a deskilling of the workforce (Arnold & Sutton 1998; O'Leary 2002b), but no prior empirical research has examined these issues in a KMS setting.

KMS is an emerging stream of research, and numerous authors have provided general descriptions of KMS to guide future research (Alavi & Leidner 1999, 2001; Davenport 1997; Dilnutt 2002; Leech & Sutton 2002; O'Leary 2002a, 2002b). Further, in an attempt to detail specific features and functionalities, several authors have documented problem studies on specific firms and their KMS use (Alavi 1997; Baird et al. 1997; Bartlett 1996; Henderson & Sussman 1997; Watts et al. 1997; Wickramasinghe & Mills 2002). Finally, a few studies have started to develop theory regarding KMS design and examine the effects of various KMS features (Earl 2001; Markus 2001;

Poston & Speier 2005). Although the infantile KMS literature has speculated about the actual transfer of knowledge associated with a KMS, this stream of literature has yet to actually investigate any implications of KMS use and knowledge transfer (Grover & Davenport 2001; Alavi & Leidner 2001).

Intelligent decision aid literature, on the other hand, has examined knowledge acquisition and the corresponding impact associated with the use of various intelligent decision aids. Murphy (1990), followed by Eining & Dorr (1991) pioneered a now well-developed stream of literature that investigated the effects of intelligent decision aids and their components on knowledge acquisition (Brody et al. 2003; Glover et al. 1997; Hornik & Ruf 1997; Mascha 2001; Odom & Dorr 1995; Pei et al. 1994; Rose & Wolfe 2000; Rose 2005; Smedley & Sutton 2004b, 2004a; Steinbart & Accola 1994). Murphy (1990) found that intelligent decision aids, with and without explanations, resulted in significantly worse performance than did a manual aid, whereas Eining & Dorr (1991) found that intelligent decision aids resulted in significantly improved procedural knowledge acquisition than did the control group or the users of simplistic questionnaires. These conflicting results provided motivation for later studies to uncover the effects of intelligent decision aids and their components on knowledge acquisition and performance.

Intelligent decision aids are notorious for reducing cognitive effort, while not increasing information usage (Todd & Benbasat 1992, 1994; Glover et al. 1997); and users tend to rely on strategies, which require less cognitive effort (Todd & Benbasat 1994). This cognitive effort phenomenon may be responsible for the varying effects of intelligent decision aids on knowledge acquisition and performance and may extend to KMS use. Intelligent decision aids have been shown to decrease task related knowledge (Glover et al. 1997), decrease declarative knowledge acquisition (Brody et al. 2003), increase novice performance (Fedorowicz et al. 1992; Lamberti & Wallace 1990), and increase knowledge acquisition (Fedorowicz et al. 1992). In an effort to assist in knowledge acquisition associated with intelligent decision aids, researchers investigated the effects of rules and examples embedded within intelligent decision aids on knowledge acquisition. An intelligent decision aid embedded with example based explanations resulted in greater performance than an intelligent decision aid without explanations (Hornik & Ruf 1997). Rules embedded within an intelligent decision aid led to an increase in declarative and procedural knowledge acquisition (Pei et al. 1994). These results suggest that examples embedded within a KMS may increase performance, while rules embedded within a KMS may increase both declarative and procedural knowledge acquisition.

Anderson's Adaptive Control of Thought – Rational (ACT-R) theory (Anderson 1993; Anderson & Lebiere 1998; Anderson et al. 2004) is the basis for the arguments set forth in this study regarding knowledge acquisition. Although ACT-R was originally developed based on research associated with programming, list memory, language acquisition, arithmetic, and scientific discovery, the theory has sustained prominence across these diverse domains and has been examined by other researchers in both accounting and intelligent decision aid studies. For instance, Bonner & Walker (1994), relying on Anderson's (1982) distinction between declarative and procedural knowledge, investigated the link between experience and knowledge and found that practice with explanatory feedback and any type of instruction produces procedural knowledge. Further, the results indicated that instruction and no experience or instruction and practice with no feedback did not aid in procedural knowledge acquisition (Bonner & Walker 1994). Extending Bonner & Walker were several studies relying on Anderson's ACT theories. Researchers posited that procedural knowledge was responsible for accounting expertise (Herz & Schultz 1999) and found that declarative knowledge was an antecedent to procedural knowledge (Roberts & Ashton 2003; Roberts & Dillard-Eggers 2005). A related effect has been observed in the use of explanations in an intelligent decision aid environment where novice decision makers used more declarative knowledge level explanations while experts used more procedural knowledge level explanations during completion of a judgment task (Arnold et al. 2006).

Libby's (1995) model, The Antecedents and Consequences of Knowledge, set forth a theory of accounting judgment performance, acting as a catalyst stimulating a now prevalent stream of literature. Libby's model identified knowledge and ability as primary determinants of accounting judgment performance. Further, ability and experience were identified as key factors contributing to knowledge (Libby & Luft 1993; Libby 1995). Libby's model was supported and preceded by two influential literature reviews covering experience, knowledge acquisition, and expertise of accountants – (Bonner & Pennington 1991; Waller & Felix 1984). In an effort to find a less costly facilitator of knowledge acquisition, Earley (2001) studied the effects of self explanation and found that self explanation increased procedural knowledge acquisition. Also, example use became an important factor of study and was found to decrease declarative knowledge acquisition (Bonner et al. 1992) , decrease procedural knowledge acquisition (Wynder & Luckett 1999), and increase performance (Roberts & Dillard-Eggers 2005; Wynder & Luckett 1999). On the other hand, another key factor, understanding rules, was found to increase task performance and procedural knowledge acquisition (Wynder & Luckett 1999).This stream of literature suggests that KMS will affect procedural knowledge acquisition and that examples embedded within a KMS will likely improve performance while hindering procedural knowledge acquisition and that rules embedded within a KMS will support procedural knowledge acquisition.

Prior research provides a foundation to support hypotheses about the impact of KMS use. The next section discusses the theory and develops the hypotheses.

THEORY & HYPOTHESES

In order to examine the impact of KMS use on the knowledge acquisition process, Anderson's ACT-R theory (Anderson 1993; Anderson & Lebiere 1998; Anderson et al. 2004) is discussed to provide a basis for the hypotheses development with respect to the knowledge acquisition process and the Theory of Technology Dominance (Arnold & Sutton 1998) is discussed to provide a basis for the arguments set forth with regard to the knowledge acquisition process associated with knowledge based technology use. This section summarizes the ACT-R theory and the Theory of Technology Dominance and describes the stages of skill acquisition and the effects of technology use in more detail to provide a foundation for the hypotheses.

Adaptive Control of Thought-Rational (ACT-R)

ACT-R is an integrated theory of cognition and encompasses skill acquisition, visual attention, motor movement, working memory, and scientific reasoning (Anderson et al. 2004). Two important attributes of the theory guide the hypotheses development: (1) the distinction between declarative knowledge and procedural knowledge and (2) the assumption of rational analysis.

First, a critical attribute of the theory, often cited in literature, is the distinction between declarative knowledge and procedural knowledge. Declarative knowledge is knowledge of general facts, rules, and definitions and is easily describable. In contrast, procedural knowledge is indescribable and only identified through behavior. Procedural knowledge is knowledge of how to apply declarative knowledge in solving problems (Anderson 1976, 1983, 1990, 1993; Anderson & Lebiere 1998; Anderson et al. 2004).

Second, another important feature of ACT-R is the rational analysis assumption. Rational analysis is based on the assertion that cognition adapts to the environment or optimizes behavior (Anderson 1990). Rational analysis is supported by evidence that cognition maximizes achievement of goals while also minimizing cost, in terms of time required for processing (Anderson 1993).

Knowledge Acquisition

Anderson proposes that knowledge acquisition occurs in a four-stage process: (1) analogy to example (hereafter, interpretive problem solving), (2) abstract declarative rules, (3) production rules, and (4) retrieval of example (hereafter, instance retrieval). Interpretive problem solving is defined as the interpretive application of abstracted declarative knowledge from an example (Anderson 1993). Abstract declarative rules are rules that an individual has abstracted from previous problem solving episodes (Anderson et al. 1997). Production rules are the elements of procedural knowledge and specify how to apply declarative knowledge in solving problems (Anderson & Lebiere 1998). Instance retrieval is simply the recall of a specific example in memory that is identical to the problem the individual is currently solving. The answer to this specific example in memory is returned as the answer to the current problem (Anderson et al. 1997). According to ACT-R's assumption of rational analysis, the individual will operate in the most optimal stage (Anderson 1993). The four stages are overlapping and an individual will operate within the stage in which the maximum benefit is achieved, while minimizing costs (in terms of time), at that point in time respective of the knowledge required to solve the particular problem.

Anderson's (Anderson et al. 1997) four stages of knowledge acquisition can be modeled with a declarative knowledge embodied component and a procedural knowledge embodied component. Anderson's four stages of knowledge acquisition fit neatly into the Two Component Model of Knowledge Acquisition, which is shown in Figure 1. *Interpretive problem solving*, abstract declarative rule use, and instance retrieval are embodied in the *declarative component*, as they operate on declarative knowledge. *Interpretive problem solving* is solving problems by using analogy to examples from declarative memory or an external source (Anderson 1993). Abstract declarative rules are *rules* that have been encoded into declarative memory, resulting in *declarative knowledge acquisition*. Instances are *examples* that have been encoded into declarative memory, resulting in *declarative knowledge acquisition*. Production rules are embodied in the *procedural component* of the model, as they are pieces of procedural knowledge contained in procedural memory.

The Two Component Model of Knowledge Acquisition, in Figure 1, illustrates the processes that direct *declarative knowledge acquisition* and *procedural knowledge acquisition*. As an individual encounters *declarative knowledge*, such as *rules* and *examples*, he/she has an opportunity to encode this *declarative knowledge* into declarative memory (i.e. *declarative encoding*), resulting in *declarative knowledge acquisition*. Each time an individual encounters an *example* or uses *rules* in solving a problem, he/she has an opportunity to abstract relationships and encode an abstract declarative rule into declarative knowledge (i.e. *declarative encoding*), resulting in *declarative knowledge acquisition*. As experience increases with the use of this abstract declarative rule, it can be compiled into a production rule (i.e. *production compilation*), resulting in *procedural knowledge acquisition*. Likewise, each time an individual uses an *example* to analogize and solve a new problem by means of *interpretive problem solving*, the individual has an opportunity to encode the analogy process in declarative memory (i.e. *declarative encoding*), resulting in *declarative knowledge acquisition*. Gradually the analogy process is compiled into a production rule (i.e. *production compilation)*, resulting in *procedural knowledge acquisition* (Anderson et al. 1997).

As experience increases with the use of production rules, the production rules may be made more efficient through composition (i.e. the merging of two existing production rules, which fire in sequence, to create a single new production rule (Lovett & Anderson 2005)) and proceduralization (i.e. the creation of a new production rule which encapsulates previously retrieved declarative knowledge into an existing production rule (Lovett & Anderson 2005)), resulting in *production compilation* and *procedural knowledge acquisition*. This is illustrated in Figure 1 as the recursive process between *production compilation* and *procedural knowledge acquisition*. Note that in the Two Component Model of Knowledge Acquisition, all methods of production rule creation are referred to as production compilation. Therefore, production rule compilation represents composition, proceduralization, declarative production compilation, and production rule creation by interpretive problem solving.

After procedural knowledge has been acquired, *subsymbolic knowledge acquisition* occurs. Subsymbolic knowledge acquisition is enhancement of the subsymbolic parameters, which control access to knowledge. As experience increases with the use of production rules, these subsymbolic parameters are continually updated (i.e. *subsymbolic knowledge acquisition*), thereby tuning procedural knowledge, and resulting in *procedural knowledge acquisition* (Anderson & Lebiere 1998).

Interpretive Problem Solving

When an individual does not have the requisite knowledge to solve a problem, he/she refers to an example to solve the problem (i.e. interpretive problem solving) (Anderson 1993). For example, if a new manager is trying to make a decision of whether to accept a special order, he/she could refer to the previous manager's report on a special order decision (i.e. an example). The new manager could replace the information from the previous example with the information from the current problem. The new manager could then make a decision by analogizing from the previous example, thereby using interpretive problem solving. A KMS contains a multitude of examples with varying uniqueness, which can be used in reference to solve a problem. Interpretive problem solving is an important part of the knowledge acquisition process as it is one method of creating production rules and often used as an alternative to procedural knowledge (Anderson 1993).

Although interpretive problem solving is often used when an individual does not have the necessary knowledge to solve the current problem, it is also used when the necessary knowledge is available. In fact, interpretive problem solving is in constant competition with procedural knowledge (Anderson 1993). Anderson (1993) refers to interpretive problem solving as a "meta-production", as it is considered a production with its own expected utility. A production's expected utility is a function determined by the probability that a production will successfully achieve the goal and the cost (in terms of time) to achieve the goal (Anderson et al. 2004). The individual will use the knowledge (interpretive problem solving or procedural knowledge) with the highest expected utility.

Interpretive problem solving is an increasing function of itself such that the more interpretive problem solving is used, the more likely it will be used in the future. Further, individuals will choose to use interpretive problem solving rather than create a production rule because the creation of a production rule is considered a demanding process. In fact, Anderson (1993) suggests that production rule creation is a quite expensive process, which includes setting up a control structure and probably requires sufficient space to store. Anderson (1993) contends that an individual will not create a production rule unless he/she is quite confident that the production rule will be used in the future. Therefore, the expense required may deter an individual from creating a production rule and instead encourage interpretive problem solving use, especially if interpretive problem solving use is facilitated in the problem solving process, such as in the case of the availability of knowledge within a KMS.

The research just discussed suggests that in cases when interpretive problem solving will generate a higher expected utility, when interpretive problem solving has been used in the past, and when the cost of creating production rules is higher than the cost of using interpretive problem solving, the individual will fail to acquire or fail to use any acquired procedural knowledge and will instead rely on his/her interpretive problem solving skills. A KMS will create an environment that will make these conditions more likely. A KMS provides a multitude of examples and accompanying requisite declarative knowledge components (i.e. definitions and rules). The easy access and availability of these examples and the related declarative knowledge components will reduce the cost associated with using interpretive problem solving. Further, each time interpretive problem solving is used, the individual will be more likely to use it again when solving problems in the future. This will strengthen the use of interpretive problem solving skills and in turn also further reduce the cost of using interpretive problem solving skills. Expected utility will also increase, since it is a decreasing function of the cost (time required) – cost decreases, thereby increasing expected utility.

A KMS should facilitate and improve interpretive problem solving skills by providing very easy access to a rich set of declarative knowledge components necessary to use interpretive problem solving skills. Anderson argues that interpretive problem solving methods are most successful when they draw from a "rich representation of the knowledge" (Anderson 1987). Interpretive problem solving abilities will be improved for users of KMS, who have easy, organized access to numerous examples and a complete set of the necessary declarative knowledge components.

Prior research has provided evidence that suggests that KMS use will improve interpretive problem solving abilities. An environment facilitating and supporting example use will invoke example based knowledge acquisition (i.e. interpretive problem solving) (Taatgen & Wallach 2002). Research has also indicated that individuals increase performance on problems that are very similar to an available example (Catrambone 1995). This performance is likely attributable to interpretive problem solving, since the problems being solved are similar to an available example. In a KMS setting, McCall et al. (2005) found that individuals with access to a KMS improved interpretive problem solving skills more than did individuals accessing traditional materials. These studies support the contention that the availability of declarative knowledge, through an information system, will improve interpretive problem solving skills.

The availability of numerous examples with varying uniqueness and the accompanying declarative knowledge components within a KMS will encourage and strengthen the use of interpretive problem solving skills. Although individuals having access to traditional materials (e.g. accounting manuals, textbooks) will also have access to examples, these examples will not be easily accessible and organized and the cost associated with seeking out these examples will deter individuals from searching for and using them on a continuous basis (i.e. using interpretive problem solving on a continuous basis). Also, recall that individuals prefer examples; therefore, even if an environment is conducive to example use and rule use, individuals will tend to rely on the examples in solving problems. Therefore, Hypothesis 1 investigates the improvement in interpretive problem solving skills.

H_1: An individual accessing a KMS (embedded with examples, rules, and definitions) in problem solving will strengthen interpretive problem solving skills more than an individual referencing traditional materials.

A related question is whether an individual accessing a KMS will use and improve interpretive problem solving skills differently when having access only to examples or only to rules. Prior research indicates that individuals supported by rule based knowledge will acquire rule based knowledge (i.e. abstract declarative rules and production rules), while individuals supported by example based knowledge will acquire interpretive problem solving skills (Taatgen & Wallach 2002; Anderson & Fincham 1994; Anderson et al. 1997). In addition, recall that individuals actually prefer to use examples (Pirolli & Anderson 1985; Chi et al. 1989; Ross 1987; LeFevre & Dixon 1986).

Interpretive problem solving skills are relied upon when an individual has no declarative knowledge or procedural knowledge (i.e. declarative rules or procedural rules) specific to the task at hand, when interpretive problem solving will generate a higher expected utility, when interpretive problem solving has been used in the past, and when the cost of creating production rules is higher than the cost of using interpretive problem solving. A KMS embedded with examples will make the above conditions more likely. The availability and easy access of examples, within an example based KMS, will reduce the cost of interpretive problem solving use, which will in turn increase the likelihood that interpretive problem solving will be used in the future. The cost, in terms of time, should continue to decline and the expected utility should increase. The likelihood that the individual will use interpretive problem solving in the future should continue to increase. On the other hand, these conditions are unlikely to occur with the use of a rule based KMS. The rule based KMS is embedded with rules, which facilitate rule use and rule creation but not interpretive problem solving. In addition, interpretive problem solving is defined as solving problems by means of analogizing from previous examples. In a rule based KMS, there are no examples to analogize from and therefore interpretive problem solving cannot take place.

The easy, organized access to numerous, varying examples within a KMS, embedded with examples will encourage and support an individual's interpretive problems solving skills thereby also strengthening these skills and increasing the possibility these skills will be used in the future. Therefore, Hypothesis 2 investigates the improvement in interpretive problem solving skills of users of example based KMS and users of rule based KMS.

H_2: An individual accessing a KMS embedded with example knowledge components will improve interpretive problem solving skills more than an individual accessing a KMS embedded with rule knowledge components.

Interpretive problem solving skills are key pieces of knowledge that can be used in problem solving. However, individuals must also acquire knowledge that they can use to solve problems when examples from which to analogize are not available.

Declarative Knowledge Acquisition

While interpretive problem solving is a key knowledge component and is beneficial in situations when examples are readily available, declarative and procedural knowledge allow individuals to solve problems that have never been encountered before, particularly when examples are unavailable (Anderson et al. 2004). Declarative knowledge is knowledge that individuals consciously understand and can therefore describe (Anderson & Lebiere 1998). An example of declarative knowledge is that opportunity cost is defined as the benefit forgone when another alternative is selected. This knowledge can be recalled from long term declarative memory and described.

Figure 1 illustrates declarative knowledge acquisition as the declarative encoding of declarative knowledge, such as rules and examples. Declarative encoding is the process of storing declarative knowledge into declarative long term memory. Declarative knowledge is acquired in one of two ways: exposure to the environment or as the solution to a problem solved (Anderson & Schunn 2000). Objects that are attended to in the environment are passively encoded into long term declarative memory as observations from the environment. For example, in a special order decision, a manager may be told by staff that the minimum acceptable special order sales price is $14, which is the total variable cost of the product. This is passive encoding of declarative knowledge. An individual may also acquire declarative knowledge as a result of solving a problem (Anderson & Lebiere 1998). For example, the manager may calculate the minimum special order sales price by adding all applicable variable costs. This would be active generation of minimum special order sales price. In other words, declarative knowledge can be acquired in a passive, receptive mode (encoding of observations from the environment) or in an active, generative mode (storing the results of past mental computations from the action side of a production rule) (Anderson & Schunn 2000).

Declarative knowledge is symbolized in ACT-R by chunks. Chunks are "small independent patterns" (Anderson & Lebiere 1998) of declarative knowledge with associated subsymbolic parameters. The subsymbolic parameters control access to these chunks or pieces of declarative knowledge. The retrieval of a chunk depends on its subsymbolic parameter, or activation, during a specific problem solving episode. Activation depends on the number of times the chunk has been retrieved in the past (i.e. base level activation) and the number of chunks related to the element (i.e. strength of association) in the current problem solving episode. Each time a chunk is retrieved its base level activation increases, thereby increasing its total activation and increasing the probability of future retrieval (Anderson & Lebiere 1998).

The use of a KMS should impact the declarative knowledge acquisition process. Recall that declarative knowledge is acquired in a passive, receptive mode or in an active, generative mode. Passive encoding from the environment is more accurate, while active computation strengthens those computation skills (Anderson & Schunn 2000). As indicated in Figure 1, each time a declarative knowledge component is encountered, an opportunity is presented to encode them into declarative memory.

A KMS embedded with declarative knowledge, including definitions, rules, and examples, provides users with a vast amount of declarative knowledge to be used in problem solving. The easy access and availability of this massive amount of declarative knowledge increases an individual's opportunity to encode these declarative knowledge components. However, three issues arise that may impede the encoding of declarative knowledge when using a KMS.

First, the multitude of information as well as the multiple ways of accessing this information may increase the cognitive complexity and corresponding required cognitive load in using a KMS. Cognitive complexity has been found to decrease knowledge acquisition in an intelligent decision aid setting (Rose 2005; Rose & Wolfe 2000). However, search facilities and ease of access may reduce the risk of increased cognitive complexity.

The second and more significant issue is that the easy, organized access to the declarative knowledge may encourage an individual to over-rely on a KMS, similar to findings in the intelligent decision aid literature (see Arnold & Sutton 1998 for a review). The individual focused on problem solving, supported by the KMS, may transport the declarative knowledge accessed in the KMS to active memory and use interpretive problem solving. If the individual has near immediate, easy access to declarative knowledge within the KMS, he/she can over-rely on that access and have no need to encode the declarative knowledge into declarative memory. Evidence consistent with this contention has been found in the use of intelligent decision aids through reduced cognitive effort (Todd & Benbasat 1994, 1992) and is expected to make a user susceptible to technology dominance (Arnold & Sutton 1998), an effect that has been found to occur in both tax and insolvency environments (Arnold et al. 2004; Masselli et al. 2002; Noga & Arnold 2002). Also, KMS researchers have suggested that KMS use may lead to a dwindling in expertise over time (O'Leary 2002b). In fact, KMS users have been shown to acquire less declarative knowledge than users of traditional materials (McCall et al. 2005).

Finally, individuals prefer to use examples in problem solving (Pirolli & Anderson 1985; Chi et al. 1989; Ross 1987; LeFevre & Dixon 1986), and this tendency may be exacerbated by a KMS embedded with examples. Since knowledge acquisition is facilitated by abstract declarative rules (Pirolli & Anderson 1985), declarative knowledge acquisition will be impaired if an individual relies on the availability of examples to use in interpretive problem solving and never extracts the declarative representation of relationships .

On the other hand, a user of traditional materials, lacking easy access to declarative knowledge, will have to search through various materials to find the relevant declarative knowledge to solve the problem. This costly search will deter individuals from using interpretive problem solving to solve problems when referencing traditional materials (on a continuous basis), since each time the individual solves a problem using interpretive problem solving, he/she will have to search through various sources to find the relevant knowledge. Individuals referring to traditional materials then will tend to actively generate problem solutions by abstracting relationships that can be used in later problem solutions. This active generation and abstraction of relationships increases declarative knowledge acquisition (Anderson & Fincham 1994; Anderson et al. 1997; Anderson & Schunn 2000). Further, this active involvement in problem solving, required when referring to traditional materials, has been shown to increase declarative knowledge acquisition (Glover et al. 1997).

Easy organized access to multitudes of varying declarative knowledge components available through a KMS may impede declarative knowledge acquisition by encouraging interpretive problem solving, and thereby reducing relationship abstraction, increasing cognitive complexity, and reducing cognitive effort; while traditional materials, requiring more effort and cost in terms of time deter interpretive problem solving, thereby enabling declarative knowledge acquisition. Hypothesis 3 investigates the declarative knowledge acquisition of KMS users and individuals referencing traditional materials.

H_3: An individual accessing a KMS (embedded with examples, rules, and definitions) in problem solving will acquire less declarative knowledge than an individual referencing traditional materials.

If declarative knowledge acquisition is impeded by KMS use, discovering the source of the problem is critical and incorporating design features to mitigate the problem must be considered. Two specific components provided by a KMS that are addressed in the literature are examples and rules. Prior literature indicates that examples will improve problem solving (Anderson 1993; Anderson & Fincham 1994; Anderson et al. 1997; Roberts & Dillard-Eggers 2005; Hornik & Ruf 1997; Wynder & Luckett 1999) and impair declarative knowledge acquisition (Bonner et al. 1992) and procedural knowledge acquisition (Odom & Dorr 1995; Wynder & Luckett 1999). Further, research finds that rules facilitate declarative knowledge acquisition (Pei et al. 1994) and procedural knowledge acquisition (Anderson & Fincham 1994; Anderson et al. 1997; Taatgen & Wallach 2002; Wynder & Luckett 1999; Pei et al. 1994). Whether these effects are also exhibited within a KMS environment must be examined so that future KMS designs incorporate these considerations.

A KMS embedded with rules will provide users with rules that can be encoded into declarative memory or accessed at any point in time to solve problems. Acquisition of knowledge requires the development of relationships among knowledge components and integration of this new knowledge with existing knowledge (Glaser & Bassock 1989). Developing relationships and integration of the new knowledge with existing knowledge requires active involvement and effort from the individual (Glover et al. 1997). KMS embedded with rules provide the user with relationships among the knowledge components enabling integration and reducing the cognitive effort. On the other hand, a KMS embedded only with examples will not provide the relationships among knowledge components and the individual must abstract the relationships from examples within the KMS in order to acquire declarative knowledge.

Researchers have found that although participants can acquire knowledge from studying just one or a few examples and then use the knowledge in new problems, this was only possible when the examples explained why certain information was important (Chi et al. 1989; Chi et al. 1994). Further, research indicates that procedural knowledge acquisition requires that examples show the underlying principle for applying each step (Chi & Bassock 1989), and that procedural knowledge acquisition requires that the underlying rules be explicitly taught (Voss 1987). This suggests then that in a KMS environment, if only examples are referred to, it is unlikely that knowledge will be acquired.

An individual accessing examples will be prone to example based, more passive problem solving strategies and will acquire less declarative knowledge than an individual accessing a rule based KMS. Therefore, H4 investigates the declarative knowledge acquisition of users of KMS embedded with rules and users of KMS embedded with examples.

H_4: An individual accessing a KMS embedded with example knowledge components will acquire less declarative knowledge than an individual accessing a KMS embedded with rule knowledge components.

Declarative knowledge is an important element of skill and any effects of KMS use on declarative knowledge acquisition must be explored.

Procedural Knowledge Acquisition

While declarative knowledge is an important component of skill, the use of declarative knowledge requires interpretation by procedural knowledge. Although interpretive problem solving and declarative knowledge are very important components of knowledge, procedural knowledge is responsible for the development of expertise (Herz & Schultz 1999).

Procedural knowledge is knowledge of how to apply declarative knowledge in solving problems (Anderson & Lebiere 1998) and is the knowledge that controls thoughts (Anderson et al. 2004). Procedural knowledge cannot be described since individuals are not consciously aware of this knowledge (Anderson & Lebiere 1998), and is symbolized by production rules that specify how to retrieve and apply declarative knowledge in a problem solving episode.

Production rules are condition action pairs that can be likened to if-then statements in program code. The condition side of the pair specifies what must be true for the pair to apply. The action side specifies a set of steps or actions that take place if the condition is true. Each production rule is a basic step in problem solving (Anderson & Lebiere 1998) and as such each production rule typically performs one basic step in the problem solving episode.

As an example of typical production rule use in a problem solving episode, consider the previous example where the manager is trying to make a decision on whether to accept a special order. The declarative facts are as follows: the variable manufacturing cost is $10, the variable selling cost is $4, the customer is offering to pay the company $13 a piece for the product, and the variable selling cost is reduced by $2 as a result of the special order. The manager will have to use several production rules to process these declarative facts and solve the problem (i.e. make the decision of whether to accept the special order). Refer to Figure 2 for an example of the series of production rules that must be used. Basically, the manager must first add the two variable costs, $10 + $4, to obtain a total variable cost of $14. The manager must then use a second rule to subtract the $2 savings in variable selling cost from the total variable cost of $14, to obtain a revised total variable cost for the special order of $12. The manager must then use another production rule to compare the revised total variable cost for the special order of $12 with the proposed special order sales price of $13. Another production rule must be used to accept the special order since the special order sales price is greater than the revised total variable cost.

Production rules are created through dependency structures. A goal is created to understand one step in a problem solving episode. As soon as the goal is achieved and the problem solving step is understood, a production rule is automatically compiled to embody that problem solving step. This production rule is then available for use, but remains in competition with interpretive problem solving skills (Anderson & Lebiere 1998).

The Theory of Technology Dominance (Arnold & Sutton 1998) provides a foundation for how procedural knowledge acquisition will be affected by KMS use. The Theory of Technology

Dominance suggests that the use of a KMS will hinder procedural knowledge acquisition (which is argued to be responsible for expertise (Herz & Schultz 1999)). The theory sets forth propositions associated with deskilling of users of intelligent decision aids and the resultant degradation of organizational knowledge associated with the use of such systems. Intelligent decision aids relieve users of such systems from time consuming mundane tasks that are ultimately responsible for the development of knowledge (Rochlin 1997).

The Theory of Technology Dominance posits that users of intelligent decision aid will be reliant on the system to make decisions, which will impede the development of expertise. Extending the theory to an environment in which a KMS is available to support decision making, individuals using a KMS will become overly dependant on the KMS for use in interpretive problem solving and will not develop the necessary skills or procedural knowledge (responsible for expertise) to solve problems, when the KMS is unavailable.

Prior research is mixed with respect to procedural knowledge acquisition. Research indicates that an intelligent decision aid decreases task related knowledge (Glover et al. 1997), declarative explanations embedded within an intelligent decision aid increase procedural knowledge acquisition (Smedley & Sutton 2004b), and elaborations and explanations embedded in an intelligent decision aid have no effect on procedural knowledge acquisition (Odom & Dorr 1995; Steinbart & Accola 1994). Accounting research has demonstrated that examples may increase procedural knowledge acquisition (measured by performance) (Roberts & Dillard-Eggers 2005) or may hinder procedural knowledge acquisition (Wynder & Luckett 1999). These mixed results leave us with little indication of how a KMS will affect procedural knowledge acquisition; however, the psychology literature does provide some insights into how a KMS embedded with examples might affect procedural knowledge acquisition.

Acquiring knowledge from examples and solving dissimilar problems is difficult (Catrambone & Holyoak 1990; Cooper & Sweller 1987; Pirolli 1991; Ross 1989; Reed et al. 1985). Catrambone (1995) argues and finds results in support of his contention that examples aid in performance of problems that are almost identical (likely interpretive problem solving), but that individuals gain little knowledge from such examples. In fact, when principles are provided in conjunction with the examples, knowledge acquisition is hindered due to interference from the examples. He argues that interference from examples is due to the fact that individuals tend to ignore supplemental information provided in conjunction with examples and use only the examples in solving problems (Catrambone 1995; LeFevre & Dixon 1986). This suggests then that a KMS embedded with examples, rules, and definitions, will cause users of such systems to ignore the rules and definitions and over-rely on the examples to use in interpretive problem solving.

Since a KMS provides easy access to a multitude of declarative knowledge components, the user may over-rely on this knowledge, knowing he/she can access the requisite knowledge to solve a problem at any time, and may not acquire procedural knowledge. An individual can solve a problem by using procedural knowledge or by using interpretive problem solving. A KMS facilitates and encourages interpretive problem solving by providing the user with easy access to examples and requisite declarative knowledge that can be used in interpretive problem solving. Since procedural knowledge and interpretive problem solving are constantly in competition (Anderson 1993); and a KMS facilitates and encourages interpretive problem solving and decreases the cost in terms of time associated with using interpretive problem solving; and production rule creation is a costly process (Anderson 1993), it is likely that an individual using a KMS will rely on interpretive problem solving and acquire less procedural knowledge than an individual referencing traditional materials.

An individual accessing traditional materials, on the other hand, will have to comb through scattered materials (books, manuals, colleague questioning, etc.) to find the relevant knowledge to solve a problem. In addition, an individual solving problems by means of traditional materials will not have knowledge and examples from individuals across the country and across the world to access similar examples in solving problems. Therefore, an individual accessing traditional materials will be less prone to interpretive problem solving and must rely on procedural knowledge in solving problems.

Further, an individual who actively generates computations in solving problems strengthens the generation of knowledge and rule generation mechanism (Anderson & Schunn 2000). An individual presented with material from a KMS is likely to passively obtain knowledge from the KMS and bypass the active mental computations, which strengthen rule generation, and will be less likely to acquire production rules from declarative rules.

Finally, Anderson (1993) argues that production compilation requires considerable resources and that an individual is unlikely to acquire a production rule, unless the individual is sure that he/she will reuse the rule. An individual with easy access to knowledge within a KMS will not need to create a production rule since he/she will have easy access to the knowledge within the KMS. An individual solving problems in an environment facilitating interpretive problem solving (e.g. a KMS with a multitude of examples) will be more likely to depend on these skills than to acquire rule based knowledge. Therefore, Hypothesis 5 investigates procedural knowledge acquisition.

H_5: An individual accessing a KMS (embedded with examples, rules, and definitions) in problem solving will acquire less procedural knowledge than an individual referencing traditional materials.

In order to identify the components of a KMS that most affect procedural knowledge acquisition, components must be separately examined. Theory has implications for both examples and rules; therefore, the separate effects of rules and examples are investigated to determine whether one single component is responsible for the impact on procedural knowledge acquisition. While an environment conducive to example use will facilitate interpretive problem solving use, an environment encouraging rule use will facilitate declarative and procedural knowledge acquisition (Anderson & Fincham 1994; Anderson et al. 1997; Taatgen & Wallach 2002). In other words, a task that can be solved with available examples will facilitate and encourage interpretive problem solving, while a task that can be solved with rules will facilitate declarative and procedural knowledge acquisition. A KMS embedded with examples then should enable interpretive problem solving skill acquisition, while a KMS embedded with rules should enable declarative and procedural knowledge acquisition.

Researchers have also found that although participants can acquire knowledge from studying just one or a few examples and then use the knowledge in new problems, this was only possible when the examples explained why certain information was important (Chi et al. 1989; Chi et al. 1994). Chi & Bassock (1989) found that knowledge acquisition requires that examples show the underlying principle for applying each step, whereas Voss (1987) found that knowledge acquisition requires that the underlying rules be explicitly taught (Voss 1987). Furthermore, knowledge acquisition is facilitated by abstract rules (Pirolli & Anderson 1985) and principles (Catrambone 1995). This research suggests that individuals need supplemental information with examples in order to facilitate knowledge acquisition.

Research supports the proposition that examples hinder procedural knowledge acquisition, while rules facilitate procedural knowledge acquisition. Odom & Dorr (1995) found that precise explanations with examples embedded within an intelligent decision aid did not assist in procedural knowledge acquisition. As further evidence, Wynder & Luckett (1999) find that procedural knowledge acquisition resulted from understanding rules, but not from worked examples. Further, the study finds that individuals receiving both worked examples and understanding rules did not acquire procedural knowledge, indicating that perhaps worked examples distracted the individual from acquiring procedural knowledge from the understanding rules (Wynder & Luckett 1999).

Referring to Figure 1, production rules are compiled through the production compilation process via declarative rules or the declarative encoding of the analogy process associated with interpretive problem solving. In other words, whether production rules are compiled through declarative rules or interpretive problem solving, declarative encoding must occur prior to production compilation. Furthermore, production rule compilation through interpretive problem solving requires an additional step and is characterized by a more gradual shift to production rules (Anderson & Fincham 1994; Anderson et al. 1997). Therefore, an example based KMS, promoting interpretive problem solving, will slow procedural knowledge acquisition.

Catrambone (1995) finds that individuals gain little knowledge from examples. Further, examples have been shown to aid novice performance but hinder procedural knowledge acquisition (Kalyuga et al. 2001; Marchant et al. 1991). This research suggests that examples improve performance via interpretive problem solving and that this reliance on interpretive problem solving hinders procedural knowledge acquisition, since interpretive problem solving and procedural knowledge are in competition with one another. In other words, when provided with examples, individuals tend to abandon the costly process of acquiring procedural knowledge and rely on these examples to solve problems using interpretive problem solving. Therefore, H6 investigates the impact of example based KMS use on procedural knowledge acquisition.

H_6: An individual accessing a KMS embedded with example knowledge components will acquire less procedural knowledge than an individual accessing a KMS embedded with rule knowledge components.

Once procedural knowledge has been acquired, the accuracy and timeliness of its use in problem solving depends on a subsymbolic parameter – production utility. During a problem solving episode only one of an individual's set of production rules can be selected. The production rule that is selected is the production rule with the highest expected utility. Expected production utility is a subsymbolic parameter that estimates the value of a production rule based on previous experience using the production rule. Each time a production rule is used, its cost and probability of success are updated to reflect that experience (Anderson et al. 2004).

As experience increases and an individual is more aware of the success of a production rule, the individual becomes more accurate with use of his/her set of production rules. Accuracy, then, depends on an individual's set of production rules and his/her prior experiences with these production rules.

Recall, by referring to Figure 1, that one of the methods of compiling a production rule is through interpretive problem solving. Production rule creation by interpretive problem solving occurs when an individual recognizes patterns from one or more examples and uses analogy in solving additional problems. This analogy process is then encoded into long term memory (i.e.

declarative knowledge acquisition) and a production rule is compiled from this declarative encoding of the analogy process. Since individuals using a KMS, having access to multiple examples, favor examples and ignore supplemental knowledge and are thus prone to interpretive problem solving, individuals accessing a KMS will be more likely to acquire procedural knowledge through interpretive problem solving, which research has reported creates weaknesses in procedural knowledge acquisition. An individual acquiring knowledge through interpretive problem solving will be biased toward false recognition of statements consistent with that prior knowledge. In addition, the benefit of applying prior knowledge in knowledge acquisition by analogy is lost when a cue to the old knowledge is unavailable at the time of retrieval (either generated by the individual or an external source, such as a task). Further, acquiring declarative and procedural knowledge by interpretive problem solving is only successful when there is a close relationship between the old and new knowledge (Schustack & Anderson 1979). Therefore, individuals using a KMS embedded with declarative knowledge (including examples) will be prone to relying on example use and interpretive problem solving, which leads to less accurate procedural knowledge.

H_7: An individual who acquires knowledge through solving problems with the assistance of a KMS (embedded with examples, rules, and definitions) will be less accurate in solving unfamiliar problems, in an unassisted (i.e. individuals do not have access to any materials) environment, than will an individual who acquires knowledge through use of traditional materials.

Accuracy is based on the number of production rules available and the number of times those production rules have been used. Therefore, as practice increases, accuracy increases. Accuracy then should also be affected by the use of only examples or the use of only rules. The previous discussion argued that a KMS embedded only with examples will encourage interpretive problem solving use and slow and weaken procedural knowledge acquisition. On the other hand, a KMS embedded with rules will facilitate procedural knowledge acquisition. A KMS embedded with rules will create an environment in which an individual can solve a problem via rules, which enables rule based knowledge acquisition (Taatgen & Wallach 2002). Therefore, a user of a KMS embedded with rules should acquire more procedural knowledge than an individual accessing a KMS embedded only with examples. A user of a KMS embedded with rules, having more procedural knowledge and more practice with such knowledge, should then have more accurate use of his/her procedural knowledge. Further, the user of a KMS embedded only with examples, over-relying on the examples to use in interpretive problem solving, and acquiring procedural knowledge through the declarative encoding of the analogy process, will have less accurate procedural knowledge due to the weaknesses associated with procedural knowledge acquisition from declarative encoding of the analogy process as indicated by Schustack & Anderson (1979). Therefore, Hypothesis 8 investigates accuracy in problem solving of users of example based KMS and users of rule based KMS.

H_8: An individual who acquires knowledge through solving problems with the assistance of a KMS, embedded with example knowledge components, will be less accurate in solving unfamiliar problems, in an unassisted (i.e. individuals do not have access to any materials) environment, than will an individual who acquires knowledge through use of a KMS embedded with rule knowledge components.

The more an individual practices with his/her procedural knowledge, the less time is required in problem solving. The power law of practice predicts that as practice increases latency (i.e. time required to solve a problem) decreases (Newell & Rosenbloom 1981). Further, as practice with procedural knowledge increases, latency in problem solving decreases (McKendree & Anderson 1987; Anderson & Fincham 1994; Anderson et al. 1997).

Furthermore, interpretive problem solving requires more time than problem solving while using procedural knowledge (Anderson & Fincham 1994; Anderson et al. 1997). Individuals accessing a KMS will be prone to interpretive problem solving due to the easy access and availability of numerous examples and the requisite declarative knowledge required to solve problems. On the other hand, an individual referencing traditional materials will not have access to a multitude of examples and easy access to the necessary declarative knowledge. These individuals are more likely to rely on procedural knowledge in solving problems, the fastest problem solving strategy (Anderson & Fincham 1994; Anderson et al. 1997). Therefore, an individual accessing a KMS, prone to using interpretive problem solving (the most costly problem solving strategy in terms of time), will require more time in problem solving than an individual referencing traditional materials, more likely to be using procedural knowledge (the least costly problem solving strategy in terms of time).

H_9: An individual who acquires knowledge through solving problems with the assistance of a KMS (embedded with examples, rules, and definitions) will require more time to solve unfamiliar problems, in an unassisted (i.e. individuals do not have access to any materials) environment, than will an individual who acquires knowledge through use of traditional materials.

As practice with one's procedural knowledge increases, latency decreases (McKendree & Anderson 1987; Anderson et al. 1997; Anderson & Fincham 1994). In addition, rule use requires less time in problem solving than example use (Anderson et al. 1997). Furthermore, rule use has been shown to decrease performance time, while example use does not decrease performance time (Catrambone 1995). Also, as experience increases individuals not using examples require less time than individuals using examples in problem solving (Kalyuga et al. 2001). Individuals accessing a KMS embedded with rules, relying on declarative and procedural knowledge, will require less time in problem solving than individuals accessing a KMS embedded with examples, relying on interpretive problem solving, the most time consuming problem solving strategy.

H_{10}: An individual who acquires knowledge through solving problems with the assistance of a KMS, embedded with example knowledge components, will require more time in solving unfamiliar problems, in an unassisted (i.e. individuals do not have access to any materials) environment, than will an individual who acquires knowledge through use of a KMS embedded with rule knowledge components.

Procedural knowledge is a critical component of knowledge and is considered to be responsible for expertise (Herz & Schultz 1999). As a result, understanding the impact of KMS use on procedural knowledge acquisition is an important factor to study. The next section briefly overviews the methods used to test the hypotheses.

RESEARCH METHOD

The first experiment (Experiment I) will investigate the effect of KMS use on the knowledge acquisition process. The second experiment (Experiment II) will examine the differential effects of an example based KMS and a rule based KMS on the knowledge acquisition process. Experiment I and Experiment II only differ with respect to the reference materials accessed. As indicated in Table 1, all participants are students enrolled in a cost/managerial accounting course. As indicated in Table 1, the reference materials used in Experiment I are traditional materials (i.e. textbook and lecture notes) or KMS, and the reference materials used in Experiment II are an example based KMS or a rule based KMS. All other aspects of the experiments are identical.

Experimental Procedures

The experimental procedures are identical in both experiments. Both experiments examine knowledge acquisition in three-stage experiments in which the declarative knowledge acquisition, procedural knowledge acquisition, and interpretive problem solving skills are compared across groups, as indicated in Figure 3 and Figure 4. Experiment I (Figure 3) compares knowledge acquisition of a traditional group (group 2 from Table 1) and a KMS group (group 1 from Table 1). Experiment II (Figure 4) compares knowledge acquisition of an example KMS group (group 3 from Table 1) and a rule KMS group (group 4 from Table 1). During the first stage of the experiment, as indicated in Figure 3 and Figure 4, the participants will complete a declarative knowledge pretest recall, three pretest problems, and three treatment problems. The participants will not have access to any materials during pretest recall and pretest problems. The participants will have access to their reference materials as indicated in Table 1 while solving the treatment cases. In experiment I, group 1 will have access to the KMS, while group 2 will have access to the traditional materials. In experiment II, group 3 will have access to the example KMS, while group 4 will have access to the rule KMS. During the second stage of the experiment, participants will solve nine treatment problems, again while accessing their reference materials as indicated in Table 1. Solving the 3 treatment problems during stage 1 and the nine treatment problems during stage 2 will provide participants an opportunity to encode declarative knowledge components into long-term declarative memory, create production rules, and use interpretive problem solving skills. During the third stage of the experiment, participants will complete a declarative knowledge posttest recall and solve seven posttest problems. The declarative knowledge posttest recall will indicate the amount of declarative knowledge acquired during the treatment phase. The posttest problems are used to assess participants' level of procedural knowledge acquisition, the accuracy and timeliness of any procedural knowledge acquired, and level of interpretive problem solving skills. While solving posttest problem 1, participants will have access to a set of five examples. Posttest problem 1 is identical to a previously solved problem and similar to an example in the example set and therefore problem 1 constitutes a measure of interpretive problem solving. The participants will not have access to any materials while solving the other 6 posttest problems, which measure procedural knowledge acquisition.

Experimental Task and Materials

The experimental task was designed to provide participants with an opportunity to encode declarative knowledge, utilize interpretive problem solving skills, and compile production rules. The task was also designed to measure acquisition of declarative knowledge, acquisition of procedural knowledge, use of interpretive problem solving skills, and the progression in the strengthening of acquired procedural knowledge. To enable such opportunities and measurements, a decision-making task requiring the use of examples and/or rules was appropriate. The decision-making task chosen consists of three managerial decisions: (1) special order, (2) make versus buy, and (3) product/department elimination.

The task materials are identical in both experiments. The declarative knowledge recall is presented as a pretest and posttest measure, as indicated in Figure 3 and Figure 4. The three pretest problems, measure the participants' initial level of procedural knowledge. The three treatment problems, completed on the first day of the experiment, provide opportunities for the participants to encode declarative knowledge, acquire procedural knowledge, and use interpretive problem solving skills. The nine treatment problems, completed on the second day of the experiment provide additional opportunities for the participants to encode declarative knowledge, acquire procedural knowledge, and use interpretive problem solving skills. The posttest problem 1 is identical to a treatment problem and problems in the reference materials, and constitutes a measure of interpretive problem solving. Recall that interpretive problem solving is the use of analogy to an example in solving a similar problem. The participants will have access to an example set when solving the posttest problem 1, which measures interpretive problem solving skills. Finally, the six posttest problems measure procedural knowledge.

The declarative knowledge recall instrument was developed based on common rules and definitions found in a managerial accounting textbook (Horngren et al. 2006). The pretest, treatment, interpretive problem solving, and posttest problems were developed based on a managerial accounting test manual (Gleim & Campbell 1992). The materials will be pilot tested by PhD students.

Experimental KMS

WebCT, an Internet based course portal, will be used to implement the KMS used in both experiments for several reasons. First, the WebCT interface is very similar to a lotus notes database, which is applied as the software architecture in most KMS (O'Leary 2002b). Second, the participants are proficient with WebCT as they are required to use it in several courses. Also, the WebCT environment will allow the course administrator to track student activity, including time required in solving problems, a measure necessary for hypotheses testing. Finally, WebCT will permit the course administrator to allow and deny student access, facilitating control over the KMS.

The KMS provides easy access to definitions, rules, and examples related to special orders, make versus buy, and product/department elimination. These are the types of materials that are commonly available to KMS users in a business environment. For example, examples are found in Lessons Learned databases and Best Practice databases, whereas rules and definitions are found in FAQ databases and Functional Knowledge databases.

The KMS organizes definitions, rules, and examples into either the knowledge category (definitions, rules, examples) or the decision type (special order; make versus buy; product/department elimination). The KMS main menu displays icons and links to definitions, rules, examples, special order, make versus buy, and product/department elimination. This allows the user to navigate to either a specific decision or to a specific type of knowledge.

The example KMS is identical to the KMS described above, except that the rules are excluded. The rule KMS is also identical to the KMS described in the previous paragraph with the exception that the examples are removed. This design allows for the investigation of the effects of the specific components of examples and rules on knowledge acquisition.

Measurement and Design

Table 2 illustrates the measurement and design and indicates the independent variables, the dependant variables, the test, and the experiment in which the measures were collected for each of the ten hypotheses. ANCOVAs will be used to test all of the hypotheses. In addition, the independent variable for all tests is group (KMS group or traditional group for H1, H3, H5, H7, and H9; example KMS group or rule KMS group for H2, H4, H6, H8, and H10). Two covariates will be used in the analysis of all of the hypotheses—ability and goal orientation. Research indicates that ability affects knowledge and ability and knowledge in turn affect performance (Anderson 1985; Campbell 1990; Campbell et al. 1992; Kanfer & Ackerman 1989; Libby 1995; Libby & Luft 1993). Ability is included as a covariate as it will be a factor determining declarative knowledge acquisition, procedural knowledge acquisition, and interpretive problem solving skills improvement. Participants' GPA will be used as a measure of ability. An individual exhibiting performance goal orientation tends to strive for high performance or avoid low performance. On the other hand, an individual exhibiting learning goal orientation tends to make an effort to understand something new or increase level of performance in a given activity (Button et al. 1996). Accordingly, goal orientation is included as a covariate in the models. Goal orientation will be measured using the work preference inventory scale developed and validated by Button et al. (1996).

The dependent variable for the interpretive problem solving hypotheses (H1, H2) is difference in the mean percentage score of the posttest problem 1, which measures interpretive problem solving skills, and the mean of the other six posttest problems as similarly measured by Anderson (Anderson & Fincham 1994; Anderson et al. 1997). An additional covariate for the tests of H1 and H2 will be treatment problem 5 (identical to the interpretive problem solving problem), which constitutes a measure of initial interpretive problem solving skills. The dependent variable to test H3 and H4, with respect to the acquisition of declarative knowledge will be the difference in posttest recall and pretest recall.

Individuals using procedural knowledge will exhibit speed up when solving problems in the same direction as practiced, when such procedural knowledge was acquired. The time required to solve problems in the reverse direction will require more time since the individual will need to create procedural knowledge to constitute that direction. Accordingly, to test H5 and H6, with respect to the acquisition of procedural knowledge, the dependant variable will be the mean of latency for reverse direction posttest problems less the mean latency for practiced direction posttest problems as measured by Anderson et al. (1997). An additional covariate used to test H5 and H6 will be the mean score of the pretest problems. This will control for prior performance on procedural knowledge problems.

To test H7 and H8, comparative accuracy of procedural knowledge use, the dependent variable will be number of errors, a measure used frequently by Anderson (Anderson 1981; Anderson & Fincham 1994; Anderson et al. 1997; Gunzelmann et al. 2004; McKendree & Anderson 1987). An additional covariate, mean score of pretest problems, will be included to control for prior performance.

To test H9 and H10, a comparison with respect to time required in problem solving, the time required in using the appropriate procedural knowledge must be considered. Accordingly, the incorrect answers will be omitted from this analysis as measured by Anderson (e.g. Anderson

& Fincham 1994). The dependent variable will be latency (time required to solve each problem), another measure commonly used by Anderson (e.g. Gunzelman et al. 2004, Anderson & Fincham 1994, Anderson et al. 1997, McKendree & Anderson 1987, Anderson 1981).

CONCLUSION

In an effort to sustain valuable knowledge within a firm with the ultimate goal of improving performance, firms have implemented KMS. However, concern has emerged that the long-term effects of KMS use may be detrimental. Widespread adoption of KMS has sparked concern that KMS use will result in a dwindling of expertise within the firm (O'Leary 2002b). In addition, over-reliance on technology may result in a deskilling of the work force and ultimately a lack of development of new knowledge (Arnold & Sutton 1998). A KMS may improve performance in the short run; however, if knowledge acquisition is impeded, who will develop future knowledge? If users of KMS encounter a situation in which the KMS is unavailable, will these individuals have the requisite knowledge to approach such a situation? Importantly, as individuals rise in the ranks in an organization they must possess knowledge in order to converse intelligently with clients, and if they fail to develop knowledge, they will be unable to perform these duties without access to a KMS.

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Figure 1 - Two Component Model of Knowledge Acquisition

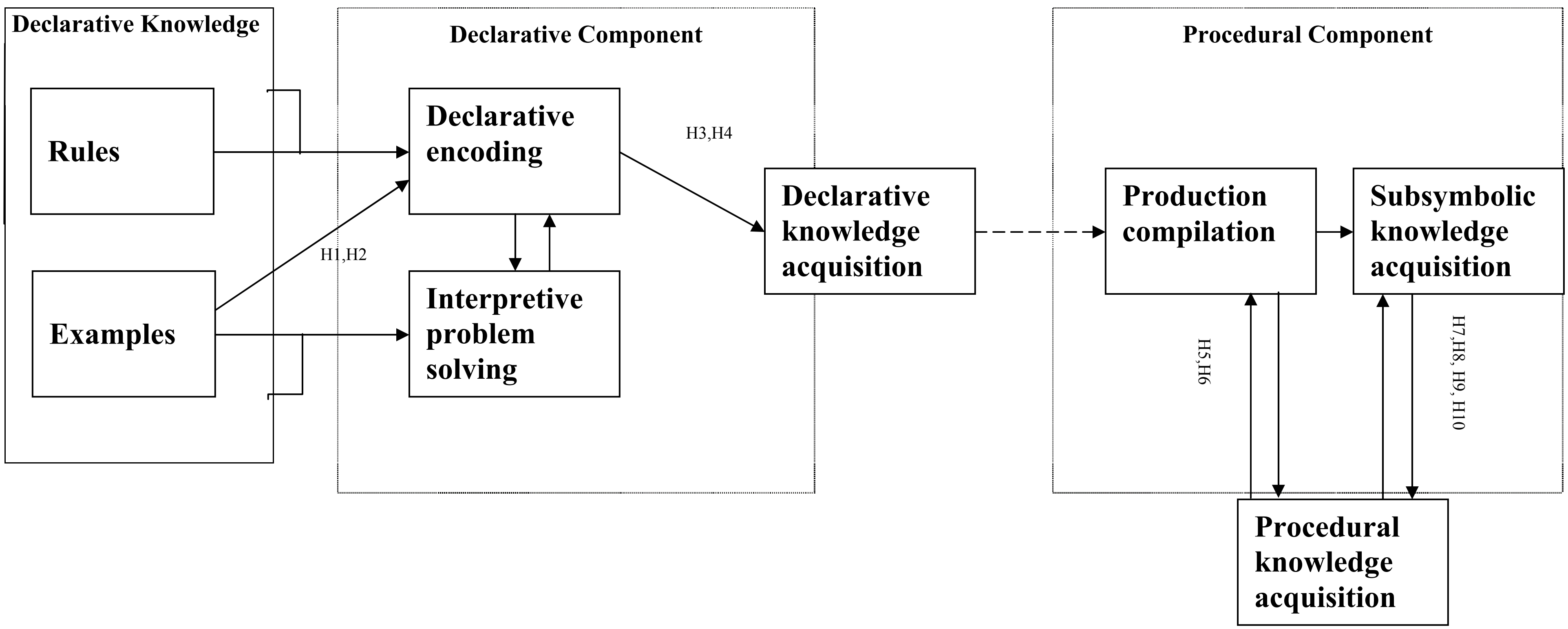


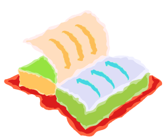
Figure 2 – Example of Production Rules for the Special Order Acceptance Decision

IF	The goal is to make a decision on whether to accept a special order
THEN	Set up a subgoal to find total variable costs for the special order
IF	The goal is to find total variable costs for a special order
THEN	Add all variable costs to calculate the total variable cost and set a subgoal to find revised total variable cost for a special order
IF	The goal is to find revised total variable cost for a special order
THEN	Subtract any savings due to the special order from the total variable cost and add any additional costs due to the special order to the total variable cost to calculate the revised total variable cost and set a subgoal to compare the revised total variable cost with the proposed special order sales price
IF	The goal is to compare the revised total variable cost with the proposed special order sales price
THEN	Subtract the revised total variable cost from the proposed special order sales price to calculate the special order profit per unit and set a subgoal to return a special order decision
IF	The goal is to return a special order decision and the special order profit per unit is greater than or equal to zero
THEN	Return the decision to accept the special order
IF	The goal is to return a special order decision and the special order profit per unit is less than zero
THEN	Return the decision to reject the special order

Figure 3
Overview of Experiment I

EXPERIMENTAL SESSION 1

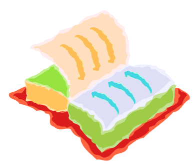
KMS Group
Complete:
Pretest Recall (definitions, rules)
3 Pretest Problems (no materials)
3 Treatment Problems (while using KMS)



Control Group
Complete:
Pretest Recall (definitions, rules)
*3 Pretest Problems (*no materials)
3 Treatment Problems (while using a textbook and lecture notes)

EXPERIMENTAL SESSION 2

KMS Group
Complete:
9 *Treatment Problems* (while using KMS)



Control Group
Complete:
9 *Treatment Problems* (while using a textbook and lecture notes)

EXPERIMENTAL SESSION 3

Complete:
Posttest Recall (definitions, rules)
* Posttest Recall less Pretest Recall - measures declarative knowledge acquired
1 interpretive problem solving Test Problem (while referring to a set of examples)
*interpretive problem solving Test Problem score less mean of all six other Posttest Problems
-measures interpretive problem solving ability
6 Posttest Problems
*latency reverse tested problems less latency of practiced direction tested problems
- measures procedural knowledge acquired
* number of errors
- measures accuracy of procedural knowledge
*latency of correctly answered problems
-measures time required in solving problems

Figure 4
Overview of Experiment II

EXPERIMENTAL SESSION 1

<u>Example based KMS Group</u>
Complete:
Pretest Recall (definitions, rules)
3 *Pretest Problems* (no materials)
3 *Treatment Cases* (while using KMS)

<u>Rule based KMS Group</u>
Complete:
Pretest Recall (definitions, rules)
3 *Pretest Problems* (no materials)
3 *Treatment Problems* (while using a textbook and lecture notes)

EXPERIMENTAL SESSION 2

<u>Example based KMS Group</u>
Complete:
9 *Treatment Problems* (while using KMS)

<u>Rule based KMS Group</u>
Complete:
9 *Treatment Problems* (while using a textbook and lecture notes)

EXPERIMENTAL SESSION 3

Complete:
Posttest Recall (definitions, rules)
* Posttest Recall less Pretest Recall - measures declarative knowledge acquired
1 interpretive problem solving Test Problem (while referring to a set of examples)
*interpretive problem solving Test Problem score less mean of all six other Posttest Problems
-measures interpretive problem solving ability
6 Posttest Problems
*latency reverse tested problems less latency of practiced direction tested problems
- measures procedural knowledge acquired
* number of errors
- measures accuracy of procedural knowledge
*latency of correctly answered problems
-measures time required in solving problems

Table 1 - Participants

Group	Experiment	Reference Materials	Participants	Approximate Number of Participants	Level of Knowledge
1	I	KMS	Cost/managerial students	35	Novices
2	I	Traditional Materials	Cost managerial students	35	Novices
3	II	Example KMS	Cost/managerial students	35	Novices
4	II	Rule KMS	Cost/managerial students	35	Novices

Table 2 - Measurement and Design

Hypothesis	Experiment	Independent Variable	Dependent Variable	Test
H_1: An individual accessing a KMS in problem solving will strengthen interpretive problem solving skills more than an individual referencing traditional materials.	**I**	IV: Group Covariates: Ability, Goal Orientation, Treatment Problem 1	interpretive problem solving problem score less mean of all posttest cases	ANCOVA
H_2: An individual accessing a KMS embedded with example knowledge components will improve interpretive problem solving skills more than an individual accessing a KMS embedded with rule knowledge components.	**II**	IV: Group Covariates: Ability, Goal Orientation, Treatment Problem 1	interpretive problem solving problem score less mean of all posttest cases	ANCOVA
H_3: An individual accessing a KMS in problem solving will acquire less declarative knowledge than an individual referencing traditional material.	**I**	IV: Group Covariates: Ability, Goal Orientation	posttest recall less pretest recall	ANCOVA
H_4: An individual accessing a KMS embedded with example knowledge components will acquire less declarative knowledge than an individual accessing a KMS embedded with rule knowledge components.	**II**	IV: Group Covariates: Ability, Goal Orientation	posttest recall less pretest recall	ANCOVA
H_5: An individual accessing a KMS in problem solving will acquire less procedural knowledge than an individual referencing traditional materials.	**I**	IV: Group Covariates: Ability, Goal Orientation, mean score of pretest cases	Latency of reverse tested problems less latency of practiced direction problems	ANCOVA
H_6: An individual accessing a KMS embedded with example knowledge components will acquire less procedural knowledge than an individual accessing a KMS embedded with rule knowledge components.	**II**	IV: Group CVs: Ability, Goal Orientation, mean score of pretestcases	Latency of reverse tested problems less latency of practiced direction problems	ANCOVA

Table 2 (Continued)- Measurement and Design

Hypothesis	Experiment	Independent Variable	Dependent Variable	Test
H_7: An individual who acquires knowledge through solving problems with the assistance of a KMS will be less accurate in solving unfamiliar problems, in an unassisted environment, than will an individual who acquires knowledge through use of traditional materials.	**I**	IV: Group Covariates: Ability, Goal Orientation, mean of pretest problems	number of errors in 6 posttest problems	ANCOVA
H_8: An individual who acquires knowledge through solving problems with the assistance of a KMS, embedded with example knowledge components, will be less accurate in solving unfamiliar problems, in an unassisted environment, than will an individual who acquires knowledge through use of a KMS embedded with rule	**II**	IV: Group Covariates: Ability, Goal Orientation, mean of pretest problems	number of errors in 6 posttest problems	ANCOVA
H_9: An individual who acquires knowledge through solving problems with the assistance of a KMS will require more time to solve unfamiliar problems, in an unassisted environment, than will an individual who acquires knowledge through use of traditional materials.	**I**	IV: Group Covariates: Ability, Goal Orientation	latency of correctly answered posttest problems	ANCOVA
H_{10}: An individual who acquires knowledge through solving problems with the assistance of a KMS, embedded with example knowledge components, will require more time in solving unfamiliar problems, in an unassisted environment, than will an individual who acquires knowledge through use of a KMS embedded with rule knowledge components.	**II**	IV: Group Covariates: Ability, Goal Orientation	latency of correctly answered posttest problems	ANCOVA