December 2002

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Abstract

The goal of this exploratory research study is to understand factors that affect the likelihood of successfully reusing someone else's knowledge vs. inventing one's own solution. We examine knowledge reuse by scientists and engineers in conjunction with their work processes in order to learn how knowledge is truly reused in the context of the work required. Our findings indicate that there are eight factors that affect the likelihood of successfully reusing other's knowledge. We also we suggest knowledge management strategies and knowledge management systems tools that may be helpful in this endeavor. Based on our findings we propose a conceptual model for efficiently finding solutions to problems for which one does not have a ready answer.

Keywords: Knowledge management, knowledge management systems, knowledge reuse

Introduction

Knowledge management (KM) is conceptualized as a series of processes embedded in individuals, groups, and physical structures with knowledge flowing between the three entities (Alavi and Leidner 2001). Knowledge management systems (KMS) refer to the technology used to support the creation, transfer, and application of knowledge (Alavi and Leidner 2001). Even though most KM projects in practice use various KMS technologies to support knowledge flows within the organization, few IS studies have addressed issues related to the design, use, or success of systems to support KM (Alavi and Leidner 2001).

KMS consists of various technology tools thus its role within the organization is varied based on the type, scope, and characteristics of the knowledge management processes (Alavi and Leidner 2001). Blacker (1995) argues that in many frameworks on knowledge transfer (e.g. Nonaka 1994) knowledge is a specific entity, formed in the minds of individuals and conceptually distinct from the work and learning processes around which organizations are structured. In such frameworks, we do not learn of how the "agent" engages in a "knowing process", we only learn how knowledge is converted independent of the work required. As such, we only learn of disembodied knowledge entities, not how knowledge is truly transferred as part of the work activity. Others have suggested, as well, that knowledge transfer cannot be separated from the work process in which it is located (Argote and Ingram 2000).

The goal of this exploratory research study is to understand knowledge reuse in the context of work processes. This study examines knowledge reuse in the context of scientist and engineer (S&E) problem solving. More specifically we ask what factors affect the likelihood that S&Es will successfully reuse other's knowledge rather than invent their own solutions. Based on our findings we propose a conceptual model for efficiently finding solutions to problems that one does not have a ready answer for. In addition, our findings allow us to suggest KM strategies and KMS tools that may be helpful in these endeavors.

Methodology

The research study took place at a private, nonprofit organization that provides scientific research, development, and advisory services. The organization is focused on the development of the best space-related hardware at the lowest prudent cost. Most of

the organization's work is hands-on engineering associated with the design, test, evaluation, and initial operation of space systems with contractors doing detailed engineering, manufacturing, delivery, and launch. We obtained eleven cases of knowledge reuse during problem solving (Table 1). The cases were obtained by interviewing S&Es nominated by managers. Managers were asked to nominate two S&Es from their department, one high reuser and one low reuser. The distinction was made to increase the range of knowledge reuse behavior and improve our understanding of factors that may affect the likelihood of successfully reusing other's knowledge vs. inventing own solution.

For each case the S&E was asked to tell us a story about a problem they solved that required reusing someone else's knowledge. Table 2 lists the interview protocol used. We asked different S&Es to focus on different situations so that we could understand the range of factors that affect knowledge reuse during problem solving. We also asked the S&Es about the knowledge sources and KM techniques (Table 3) used during the problem-solving situations. The KM techniques were adopted from the creativity and research and development literatures with regard to problem solving (Amabile 1996; Dougherty 1992; Guilford 1950; Kazanjian et al. 2000; Kirton 1976; Shockley 1972; Tomke 1998; von Hipple 1988). In addition, we asked S&Es more general questions related to problems encountered during knowledge reuse and the organizational climate for reuse. To analyze the data, the notes for all eleven cases were organized by the interview protocol questions. Both interviewers reviewed the notes for each case to identify factors that were associated with knowledge reuse. Cross case comparisons were done to determine if the factors varied by the S&Es' level of reuse or the type of problem solving story told.

Results

Although we found S&Es take various factors into consideration when looking for knowledge to reuse during problem solving, there were eight factors that were mentioned frequently and across cases. In doing cross case comparisons, we did not find the eight factors mentioned to vary by the S&Es' level of reuse or the type of problem solving story told. Due to the page limit, we do not include all the comments coded during case analysis. Instead we briefly define each factor and highlight example comments made by the S&Es. Based on our analysis we are suggesting that these eight factors affect the likelihood of successfully reusing other's knowledge vs. inventing own solution.

Organizational Climate for Reuse

The organizational climate for reuse is the S&Es' perceived message from management about the importance of reuse. An example comment is,

> "[T]hey [the managers] encourage it; they give it lip service. They say it's important to them in terms of actually encouraging it. Other than saying that they like it I can't think of any specific example. It's not like they set time aside to do it or they give you specific tools to do it. They [just] say that it's important to them."

Exposure to Potentially Reusable Knowledge

The exposure to potentially reusable knowledge represents the extent S&Es are exposed to new and diverse knowledge sources, where knowledge sources are human as well as non-human (e.g. journals, books, KMS technology). Example comments follow,

> "Over the course of 11 years I know someone. [I have] served on lots of committees and interdisciplinary [teams] and from classes [that I have] taken I have a pretty extensive network. If [our company] has 3000 people I know 1500. I can't say I keep in contact with them but I know what they do. I went to a lot of classes and [have] been on a lot of teams."

> "I had to try to estimate how much a peroxide tank would weigh. I suppose, I did [a] literature review on peroxide storage. I looked through professional journals, papers, I spoke with a couple of contacts in the industry, and I suppose I pulled a few equations out of textbooks for calculating sizes and thicknesses of tanks. I have my own storage of papers I looked through that, but I also looked in the library."

Perceived Ease of Search Effort

The perceived ease of search effort includes two dimensions. First there is the ease of navigating through technology. Second, there is the ease in defining the search. Example comments follow,

> "Our library is not very good. I think they have a lot of information but their database search engine is terrible. [It is] probably the worst I've ever seen. And so I have gone there and tried to look up a subject and I have so much difficulty using the search engine that sometimes I've just given up."

> "Sometimes [it is] difficult to come up with search criteria. So if you can help me pick up keywords and tie [them] to some external list and decision tree [that would be helpful]."

Availability of Metaknowledge about Knowledge to Be Reused

The availability of the metaknowledge is the extent to which knowledge about the potentially reusable knowledge is provided (e.g. fit, feasibility, malleability). An example comment includes,

> "[Specific characteristics of knowledge that prompt me to reuse are] real results, stuff that actually gets flown – boom weighed this with this natural frequency."

Lack of Experience with Similar Problems

The lack of experience with similar problems considers the extent to which S&Es have not had experience with the elements of the problem. An S&E states,

> "[I am] new to field. [Working in the concept design center and using the models has] opened my ideas to how design interacts with other parts. [It's my] favorite project. Great way to learn how senior [members do the job]."

Perceived Likelihood Reuse Will Facilitate Solution to Problem at Hand

The perceived likelihood reuse will facilitate solution to the problem at hand is the extent the S&Es believe they can arrive at a solution via knowledge reuse. An example comment follows,

> "[It is] fairly frequent to not find [a] specific answer to [the] problem because [the] problems are new or not even there yet. [It is because of] being at [the] cutting edge. Maybe KM could help if someone else did it [before]".

Broad Definition of the Problem

Broad definition of the problem considers the flexibility with which S&Es define the possible search space (i.e. solutions, constraints, industries, sources for reusable information). In this case we found that S&Es did not tend to define problems broadly. An example comment follows.

> "I suppose I could foresee somebody doing that [using our models or briefings for work outside of the program]. I've never done it. I've never needed any information taken out of the program. The problem is the output…is so mission specific or program specific that they don't really have any use beyond that one program."

However, in speaking with managers we found benefits associated with how broadly the S&E defines the problem.

> "[H]e looked a boundary conditions because he knew everyone else look[ed] at everything else. [He] would catch problems that others would not because [he] would look at things differently. [I]f you get one hour of his time could be worth 12 hours. [He] has a way of displaying things completely different, kind of transforms [the] problem to something [you] thought [you] understood to something abstract and [the] problem becomes different and [you] can approach [it] in different way."

Lack of Time and Money to Invent Own Solution

The lack of time and money to invent own solution considers the extent resource constraints deter S&Es from inventing their own solution. Although not specifically mentioned by the S&Es during interviews, in talking with their managers we learned possible reasons why some S&Es could have but did not take an innovative approach by inventing their own solution.

> "[We] don't have the resources to do [it] even if [we] have pay-offs."

Discussion

Based on our analysis and drawing from the IS and knowledge management literatures we propose a conceptual model (Figure 1) in which the eight factors are suggested to affect the likelihood of successfully reusing other's knowledge vs. inventing own solution. In the IS literature, research that considers factors that affect the likelihood of successfully reusing other's knowledge is limited. While the goal of KMS is to enable KM in organizations, research has shown that it can be of limited use and even present problems if not given proper consideration (Goodman and Darr 1998; Markus 2001). In the KM literature, factors considered to affect knowledge transfer (i.e. reuse) tend to focus on cognitive and/or social issues (Andrews and Delahaye 2000; Gupta and Govindarajan 2000; Szulanski 1996). However these issues tend to be studied in the absence of KMS. In both the IS and the KM literatures, scholars have appealed for research that focuses on KM as part of the work process (Alavi and Leidner 2001; Argote and Ingram 2000; Blackler 1995).

During the interviews we asked the S&Es for various problem-solving stories. This allowed us to consider the issues associated with knowledge reuse when one has advanced or limited knowledge of the discipline or problem at hand and how these different levels of expertise may influence perceptions of reuse outcomes. In addition we had S&Es consider knowledge sources found through social interactions as well as those found through interactions with the technology. Thus the model presented is intended to consider cognitive, social, and technology factors that affect the likelihood of successfully reusing other's knowledge vs. inventing own solution. Moreover, these factors are considered in the context of S&Es KM work activities. In addition to the identification of eight factors that increase the likelihood of reusing other's knowledge, we suggest corresponding KM strategies and tools that are intended to positively impact the factors (Table 4). These strategies and tools were developed based on the analysis of our interviews.

Organizational climate is a commonly recognized factor associated with knowledge reuse (Goodman and Darr 1998). In the traditional sense it is conceptualized as the extent of support offered in the form of words of encouragement and rewards (Goodman and Darr 1998). However, in our study we found that it should also be conceptualized as the extent of support offered in the form of time, money, and appropriate KM tools.

The exposure to potentially reusable knowledge is a factor that is associated with the use of strong and weak ties (Granovetter 1973). While we found evidence of this association in our exploratory study, we also found that the factor has to do with non-human knowledge sources, including journals, textbooks, available corporate KMS tools (e.g. knowledge repositories, email distribution lists), and the Internet.

In our study we found that the perceived ease of search effort should consider perceptions related to one's ease of defining the search as well as one's ease of navigation within the KMS. Addressing the former, novices seeking expertise outside of their discipline often have difficulties associated with lack of knowledge of the discipline. They may lack the expert jargon or be unable to articulate the question or problem well (Markus 2001). Considering technology may be used to conduct the search, researchers have also suggested that the ease of navigation within a KMS (e.g. via search engine and/or the use of hyperlinks) may also affect knowledge reuse (Boland et al. 1994; Goodman and Darr 1998).

Just because knowledge has been searched for and found does not mean that knowledge will be reused. In our study, the availability of metaknowledge about the knowledge was found to affect S&E reuse. Prior research suggests that metaknowledge offered about the fit, feasibility, and malleability of the knowledge allows potential reusers to understand as well as assess the knowledge being considered for reuse (Majchrzak, et al. 2001). Moreover making metaknowledge available to facilitate comprehension and assessment of reusable knowledge contributes to the actual reuse of that knowledge (Majchrzak et al. 2001). Similarly, Markus (2001) argues that knowledge producers have to consider how to best represent knowledge offered for reuse and perhaps translate it into terminology that the potential knowledge reuser can understand. We suggest using metaknowledge to help facilitate that translation process.

Lack of experience with a similar problem is similar to the notion of an expertise-seeking novice (Markus 2001). We are suggesting that the novice that lacks experience with the problem at hand needs and is more likely to want access to someone else's expertise without first acquiring the expertise for himself.

The perceived likelihood reuse will facilitate solution to the problem at hand is a factor that we have not found in the IS or KM literatures. However, this does not make it any less important. This is especially true if we consider the type of knowledge being sought for reuse. In a few cases we found that S&Es working with new, cutting edge technologies were less likely to believe knowledge reuse would help them solve their problems. However, research supporting knowledge utilization (i.e. reuse) for innovation has found that the opposite is true (Majchrzak et al. 2001).

Even though we found that S&Es did not broadly define the problem, in speaking with managers we found that this factor may be critical to knowledge reuse. In support of managers, research has found that innovators who reused other expert's knowledge did so in part because of how they defined the search (Majchrzak et al. 2001). The innovators did not approach a problem from a narrow solution window; instead they defined the problems broadly by the results they needed to achieve (Majchrzak et al. 2001). This allowed for more flexibility in searching for alternative solutions (Majchrzak et al. 2001). Moreover the reusers did not immediately discard or ignore an idea because it did not come from their immediate space community, it did not fit the immediate functional requirements, or it did not have the form expected or needed (Majchrzak et al. 2001).

Although not mentioned explicitly during the S&E interviews, we suggest a final factor, the lack of time and money to invent own solution. In speaking with managers, we believe that this factor may strengthen the relationship between the perceived likelihood reuse will facilitate solution to problem at hand and the likelihood of successfully reusing other's knowledge vs. inventing own solution.

In sum, we suggest that eight factors increase the likelihood of successfully reusing other's knowledge. Moreover, we suggest that knowledge reuse will increase problem solving efficiency. Specifically, the greater the likelihood of successfully reusing other's knowledge, the more efficiently S&Es will find solutions to problems that they do not have a ready answer for. Research on knowledge transfer supports this suggestion showing increases in productivity when knowledge is transferred from one entity to another (Baum and Ingram 1998 as cited in Argote 1999; Epple, Argote, Murphy 1996 as cited in Argote, 1999).

Conclusion

In our study there two major limitations. First being exploratory research our sample size was small; thus further empirical research with a much larger sample is necessary to confirm our model. Second, by studying a very specific instance of knowledge reuse during problem solving, we limited our research to interviews with S&Es in one organization. However, in our study we tried to address other issues scholars believe need attention. Thus we believe we have made several contributions. A major challenge in KM is the management of the knowledge flows between individuals and figuring out how to facilitate these flows such that the maximum amount of knowledge transfer occurs (Alavi and Leidner 2001). While we believe that KMS can do so, we understand that the flows vary based on the context of the work activities (Alavi and Leidner 2001, Argote and Ingram 2000; Blackler 1995). Thus our aim in this study is to examine knowledge reuse in the context of S&Es' problem solving, in order to understand how knowledge is reused as well as the work processes that require knowledge reuse. Prior KM research has drawn from different but related fields, which allows for insights into various issues associated with KMS (Alavi and Leidner 2001). In our study we attempted to consider social, cognitive, and technology factors that may increase the likelihood of successfully reusing other's knowledge. The role of KMS in the organization is multifaceted, and depends on the IT tools and capabilities organizations implement to support KM (Alavi and Leidner 2001). We have attempted to match specific KM strategies and KMS tools to the factors that affect the likelihood of successfully reusing other's knowledge, in an attempt to intervene and increase the likelihood of successful knowledge reuse.

In sum our contributions are threefold. First, we have examined knowledge reuse by S&Es in conjunction with the work processes of the S&Es. Thus we have learned how knowledge is truly reused in the context of the work required. Second, our model considers issues related to social and cognitive factors associated with knowledge reuse as well as the design, use, and success of systems that support KM. Third, our research findings have allowed us to suggest KM strategies and KMS tools to support the factors in the model and thus increase the likelihood of successfully reusing other's knowledge vs. inventing own solution.

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Table 1. Brief Description of the Eleven Cases

Case	Description of Problem
1. Sensors	Improve the accuracy of estimates for sensors on a satellite.
2. Satellite Structures	Assess the weight and size of inflatable rigidizable structures (i.e. a balloon) for satellite structures.
3. Optical Systems	Incorporate learnings about optical systems (i.e. the suspension of weights and masses) into a conceptual design of satellite structures.
4. Propellant Weight	Determine the accuracy behind an estimate of the weight of a propulsion system and the propellant.
5. Orbit Failure	Fix an orbit failure, in which a launch vehicle failed to take a satellite to a geosynchrous orbit.
6. Propulsion Model	Incorporate a new tank propellant, hydrogen peroxide, into a propulsion model for use during a conceptual study.
7. Reports	Convert reports to XML so that it would be easier for users to customize them.
8. Telescope	Stop the disturbances of a package on board a spacecraft and the operation of a telescope.
9. Power Supply	Fix a problem with satellite processing at Cape Canaveral thought to be caused by the power supply.
10. Cover Panels	Better regulate the temperature of cover panels that were designed to keep the dust and dirt out of the satellite.
11. Simulator	Get as near real-time development as possible during a simulator development project.

Table 2. S & E Interview Protocol

1) Tell a story of when you
   a) reused knowledge during an innovative problem solving approach
   b) had a problem in which you were looking for new ideas or approaches and you found knowledge from outside of your workgroup
   c) had a problem in which you were looking to resolve the problem quickly using knowledge from outside your workgroup as-is
   d) had to do research for a new technology that required you to gain knowledge that was within your domain of expertise
   e) had to do research for a new technology that required you to gain knowledge that was outside your domain of expertise
   f) used another person's knowledge during an innovative problem solving approach

2) For each story S&Es were asked to identify KM techniques used during problem solving and whether there was electronic support for them

3) For each story S&Es were asked to identify and discuss the knowledge sources available vs. those that were used during problem solving (including IT tools).

4) Have you ever looked for knowledge to answer a problem and couldn't find it? What makes some knowledge better than others? Do specific characteristics of knowledge prompt reuse? What criteria do you use when deciding whether or not to reuse knowledge?

5) What is the organizational climate for knowledge reuse?

Table 3. List of KM Techniques Referenced During Interviews

KM Techniques	Did you use this technique?	If yes, how? Was there any electronic support?
1. Look at how related disciplines have looked at problem		
2. Look at how disciplines unrelated to immediate discipline of problem might have solved a similar problem		
3. Attend to information that is seemingly irrelevant to solution of problem at hand		
4. Find problem statements used in other disciplines		
5. Receive notification of advances in unfamiliar domains such as by attending conferences on unfamiliar topics or receiving electronic alerts		
6. Searched a list of people's names in other disciplines to contact		
7. Find past failures and examine them		
8. Identify assumptions underlying proposed solutions and question them		
9. Find historical examples of assumptions that have been violated in past		
10. Generate a list of alternative problem statements		
11. Suggest and carryout thought experiments on solution		
12. Use images and metaphors when examining possible problem statement		
13. Generate a list of alternative ideas		
14. Receive notification of advances in your discipline		
15. Develop a list of criteria to compare alternative solutions based on past work on the problem		
16. Analyze historical data to create better estimates for problem		
17. Create a list of analytic models used/referenced during design meetings		
18. Create a list of parameters used as input to analytical models		
19. Create a glossary of terms used during design process		
20. Create a list of internal and external reference links used during design process		
21. Consult a list of technical questions likely to be asked during design reviews		
22. Create a decision tree describing decision rationale for choices made		

Table 4. KM Strategies and KMS Tools

Factor	KM Strategies and KMS Tools
Organizational climate for reuse	Management should provide supportive resources (i.e. time, money, tools, training) as well as traditional means of support (e.g. verbal encouragement, rewards)
Exposure to potentially reusable knowledge	Consider ways to increase exposure via captured corporate knowledge. For example, designated knowledge exchange areas that provide opportunities for both formal and informal virtual exchange.
Perceived ease of search effort	Provide a list/advertise the library and other current on-line resources and tools available in one place. Provide training for using these on-line tools and resources. Improve search capabilities allowing for more than simple keyword of KMS Provide flexible dynamically changing search options in a similar way that S&Es organize their personal files - by program, problem, part, and failures.
Availability of metaknowledge about knowledge to be reused	Consider the fact that S&Es need metaknowledge before making a decision as to its reusability and determine how best to represent this metaknowledge. What criteria or characteristics best represent malleability, feasibility, and fit within the organization? Are there other elements of metaknowledge that should be considered within the organization? Consider making physical artifacts available for possible reuse. For example, access to prototypes, fishbone diagrams, schematics, equations, models, glossary of terms, assumptions, constraints, contacts, meeting notes.
Lack of experience with similar problems	Consider the various conditions (other than new hires) when S&Es might lack experience with similar problems (e.g. attempting to reuse knowledge for innovation, seeking knowledge outside of one's discipline, broadening the definition of the problem).
Perceived likelihood reuse will facilitate solution to the problem at hand	Determine what types of knowledge are most valued by S&Es (e.g. history, failures, cutting edge technology) with respect to knowledge reusability consider ways to provide access via KMS.
Broad definition of the problem	Provide training to increase the flexibility in defining the possible search space when solving problems.
Lack of time & money to invent own solution	Increase the pressure on S&Es so that invention is not feasible.

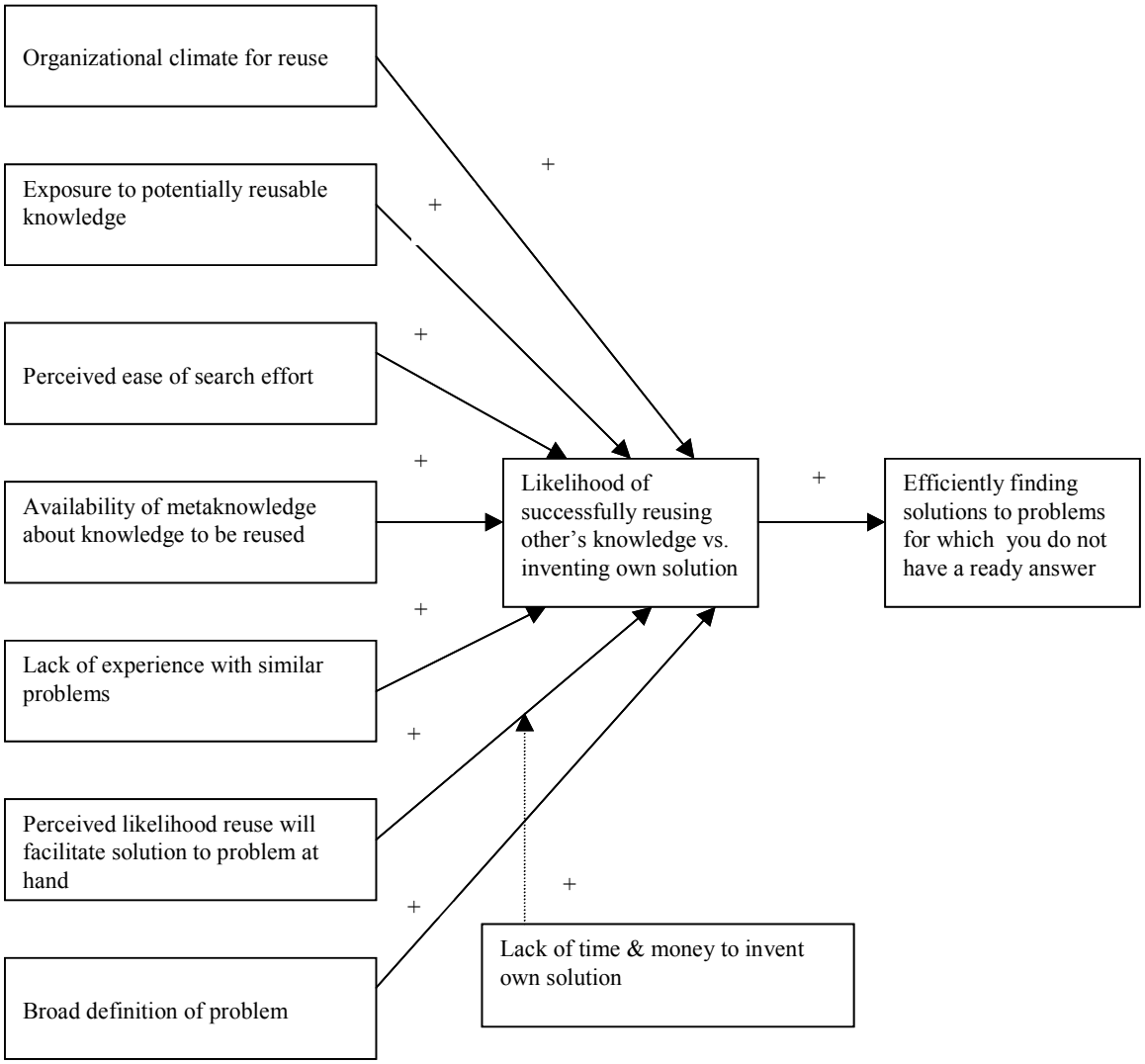

Figure 1. Conceptual Model