Organizational Knowledge Management: A Contingency Perspective

IRMA BECERRA-FERNANDEZ AND RAJIV SABHERWAL

IRMA BECERRA-FERNANDEZ is currently teaching at Florida International University. Her research focuses on knowledge management, knowledge management systems, artificial intelligence, and enterprise resource planning (ERP). Currently leading four NASA grants, she has obtained funding for over two million dollars from Kennedy Space Center (KSC), Ames Research Center (ARC), and Goddard Space Flight Center (GSFC) to develop innovative knowledge management systems. She has published extensively in leading journals including *Communications of the ACM, Knowledge Based Systems, Journal of Technology Transfer,* and *International Journal of Entrepreneurship and Innovation Management*. She earned her Ph.D. in electrical engineering from Florida International University.

RAJIV SABHERWAL is the Emery C. Turner Professor of Information Systems at University of Missouri, St. Louis. He serves as an Associate Editor for *MIS Quarterly* and frequently publishes in *Journal of Management Information Systems, Information Systems Research, MIS Quarterly, Organization Science, Decision Sciences, Communications of the ACM, Accounting, Management, and Information Technology,* and other journals. His research focuses on strategic alignment of the information systems function, knowledge management, and social aspects of systems development. He earned his Ph.D. from the University of Pittsburgh and previously taught at Florida International University and Florida State University.

ABSTRACT: Prior research examines several knowledge management processes, considering each as universally appropriate. Instead, we propose that the context influences the suitability of a knowledge management process. We develop a contingency framework, including two attributes of the organizational subunit's tasks: process or content orientation, and focused or broad domain, and links knowledge management processes to them: internalization for focused, process-oriented tasks; externalization for focused, content-oriented tasks; combination for broad, content-oriented tasks; and socialization for broad, process-oriented tasks. The empirical research was done at the Kennedy Space Center (KSC), based on several interviews and survey data from 159 individuals across 8 subunits. The results supported the contingency framework. All the knowledge management processes except externalization had a positive impact in the expected cell. At the overall level, combination and externalization, but not internalization and socialization, affect knowledge satisfaction. Some implications for practice and research are identified.

KEY WORDS AND PHRASES: contingency theory, knowledge management, structural equation modeling, task characteristics

Journal of Management Information Systems / Summer 2001, Vol. 18, No. 1, pp. 23–55.

0742–1222 / 2001 $9.50 + 0.00.

THE IMPACT OF EFFECTIVE KNOWLEDGE MANAGEMENT (KM) on business performance is well recognized [1, 7, 9, 18, 38, 40, 50, 54]. The widely held belief that the richest resource of today's organizations is the knowledge residing individually and collectively among their employees reflects the importance of processes for promoting the creation, sharing, and leveraging of knowledge [9, 12, 13, 22, 33]. A variety of tools and methodologies for this purpose have been recommended [e.g., 10, 17], and some overall knowledge management processes have been examined [e.g., 13, 18]. However, these tools, methodologies, and processes have implicitly been considered universally appropriate. This paper makes a fundamental departure from this assumption by proposing that the effectiveness of a knowledge management process is influenced by the particular context in which the knowledge is being used. More specifically, the paper addresses the following questions:

1. Do the knowledge management processes impact knowledge effectiveness?
2. Does their effect on knowledge management effectiveness vary depending on (a) whether the tasks performed using that knowledge are focused or broad in nature and (b) whether these tasks focus on "what to do?" or on "how to do it?"

This paper pursues these objectives based on an empirical investigation of one of the best-known knowledge-based organizations: the National Aeronautics and Space Administration (NASA). Specifically, the study was conducted at NASA's John F. Kennedy Space Center (KSC). KSC is responsible for the checkout, launch, and landing of the space shuttle and its payloads. The starting point for all U.S. human space flights, KSC is considered a world leader in processing and launching spacecraft that have explored and studied the earth, the moon, and planets in our solar system.

The paper is organized as follows. The following section develops the theoretical arguments leading to the research hypotheses examined in this study. The next section describes the methods used and the results of the study. Finally, the last section identifies some of the limitations of the study and examines its implications for both research and practice.

Theoretical Development

The Nature of Knowledge

KNOWLEDGE HAS BEEN DEFINED as "justified true belief" [33, p. 21]. More specifically, definitions of organizational knowledge range from "complex, accumulated expertise that resides in individuals and is partly or largely inexpressible" to "much more structured and explicit content" [10, p. 70].

The types of organizational knowledge are reflected in several classification schemes. For example, Venzin et al. [48] identify a number of categories of knowledge—including tacit, embodied, encoded, embrained, embedded, event, and procedural. Kogut and Zander [23] distinguish between "information" and "know-how" as two types of knowledge, viewing them as "*what* something means" and "knowing *how* to do some-

thing" [23, p. 386, emphasis in original]. They also identify the parallel distinction [41] between declarative knowledge (facts) and procedural knowledge (how to ride a bicycle). Another classification of knowledge views it as tacit or explicit [e.g., 37]. Explicit knowledge can be expressed in numbers and words and shared formally and systematically in the form of data, specifications, manuals, and the like. In contrast, tacit knowledge—which includes insights, intuitions, and hunches—is difficult to express and formalize, and therefore difficult to share.

The Management of Knowledge

Effective knowledge management is considered key to the success of contemporary organizations. Indeed, some authors view organizations as distributed knowledge systems [46], streams of knowledge [e.g., 51], and systems of distributed cognition [4, 53], wherein individuals act autonomously while understanding their interdependence with others. Weick and Roberts [53] use the term *collective mind* rather than *organizational mind* to highlight that organizations consist of individuals who coordinate their actions with each other. They define collective mind as a set of heedful interrelationships rather than a repository of knowledge. They also contend that the collective mind does not exist outside of human action and that it is these actions that generate the mind rather than vice versa: "We conceptualize mind as action that constructs mental processes rather than as mental processes that construct action" [53, p. 374].

The organization then serves as a knowledge-integrating institution, integrating the knowledge of many different individuals and groups in the process of producing goods and services [17, 21, 23, 31]. Knowledge integration may occur in organizations through organizational routines [30], direction [7], or processes involving the sharing of explicit or implicit knowledge [16]. The focus of this paper is on the last aspect, that is, knowledge management processes facilitating the sharing of explicit or implicit knowledge in organizations.

Explicit knowledge can be shared through various communication media, but that is not possible in the case of tacit knowledge. Tacit knowledge can sometimes be communicated through the establishment of shared understanding between individuals [37]. In other circumstances, tacit knowledge needs to be converted into an explicit form, and such conversion typically involves substantial knowledge loss. Focusing on the ways in which knowledge is shared through the interaction between tacit and explicit knowledge, Nonaka [31] identifies four possible modes: socialization, externalization, internalization, and combination.

Socialization is the sharing of tacit knowledge between individuals, usually through joint activities rather than written or verbal instructions [31]. For example, by transferring ideas and images, apprenticeships allow newcomers to see the way others think. Knowledge is produced in a group setting not only through mere acquisition of the individuals' knowledge, but also through the sharing of common understanding [14]. Social processes play an important role in the transition of knowledge across individuals or groups [20, 52, 53]. For example, one interviewee from the Engineering directorate remarked: "Each engineer had a mentor who would transfer his knowledge to the

younger engineer. This was a remarkably successful program. The engineers would tell them all the stories, for example, about Apollo. The old Apollo engineers were assigned as mentors. But now we are losing people, so how will we capture knowledge?"

Externalization involves the expression of tacit knowledge and its conversion into comprehensible forms that are easier to understand. Conventional learning methodologies require the externalization of the professor's knowledge as the initial step in the student's learning process [39]. Moreover, externalization involves techniques that help to express ideas or images as words, concepts, visuals, or figurative language (e.g., metaphors, analogies, and narratives), and deductive/inductive reasoning or creative inference [31, 32, 33].

Internalization is the conversion of explicit knowledge into the organization's tacit knowledge. This requires the individual to identify the knowledge relevant to oneself within the organization's explicit knowledge. In internalization processes, the explicit knowledge may be embodied in action and practice, so that the individual acquiring the knowledge can reexperience what others go through. Alternatively, individuals could acquire tacit knowledge in virtual situations, either vicariously by reading or listening to others' stories, or experientially through simulations or experiments. Learning by doing, on-the-job training, learning by observation, and face-to-face meetings are some of the internalization processes by which individuals acquire knowledge [31, 33].

Combination involves the conversion of explicit knowledge into more complex sets of explicit knowledge [31]. Focusing on communication, diffusion, integration, and systemization of knowledge, combination contributes to knowledge at the group level as well as at the organizational level [33]. Innovative organizations seek to develop new concepts that are created, justified, and modeled at the organizational, and sometimes interorganizational, level. Moreover, complex organizational processes require the cooperation of various groups within the organization, and combination supports these processes by aggregating technologies and knowledge [31].

All of the aforementioned processes facilitate knowledge management [33]. Each process is expected to enhance the effectiveness of knowledge management by providing individuals and groups in organizations with the knowledge needed to perform their tasks. Moreover, our focus in this study is on perceived knowledge satisfaction rather than an objective measure of knowledge effectiveness. We therefore propose the following:

H1: Internalization process is positively associated with perceived knowledge satisfaction.

H2: Externalization process is positively associated with perceived knowledge satisfaction.

H3: Combination process is positively associated with perceived knowledge satisfaction.

H4: Socialization process is positively associated with perceived knowledge satisfaction.

The Moderating Effects of Task Characteristics

This paper departs from prior research on knowledge management by arguing that the effectiveness of a knowledge management process depends on the circumstances under which it is used. In other words, instead of following the universalistic view that all four knowledge management processes are always effective, it takes a contingency theoretic view, suggesting that the impact of a knowledge management process is moderated by the context in which the knowledge is being used. The focus is on one specific aspect of the context, namely the nature of the tasks performed by the individuals and groups using the knowledge resulting from the knowledge management processes. Figure 1 summarizes the overall contingency model applied in the research study.

The underlying argument here is that the knowledge management process that a subunit should use depends on the nature of tasks it performs. This involves viewing each subunit at the aggregate level based on the predominant nature of its tasks, while recognizing that each subunit performs numerous tasks that are not all similar. This approach enables the development of mid-range theories at the subunit level, instead of the extreme approaches of viewing the entire organization as one or considering each task individually. Furthermore, this approach has considerable support in prior literature. For example, Van de Ven and Delbecq [47] offered a contingency view of the relationship between subunit tasks and organization structure, suggesting that the structure appropriate for a subunit depends on task difficulty (or the problems in analyzing the work and stating performance procedures) and task variability (or the variety of problems encountered in the tasks). Lawrence and Lorsch [25] also focused on a task characteristic—task uncertainty—at the subunit level and found subunits that perform certain, predictable tasks to be more effective when they were formally structured. Thus, a number of task characteristics have been studied at the level of organizational subunits. Two task characteristics are examined in this study as influencing the appropriate knowledge management processes, that is, task orientation and task domain. We argue that these task dimensions require different types of organizational knowledge, which in turn implies that different knowledge management processes would be appropriate [43].

Task Orientation. Recent research in the field of strategic management and organization theory has focused on the concept of task orientation for differentiating firms and organizational subunits within the firm [36]. Based on task orientation, organizational subunits have been classified into two basic categories: process-oriented and content-oriented. *Content-oriented tasks* focus on the specific ends or goals to be achieved. They concern issues such as what products need to be developed and the specific design features that need to be achieved in the products. In contrast, *process-oriented tasks* focus on the processes or means that should be used to attain the goals. They concern issues such as how to perform the processes needed to achieve the specific product design.

Content-oriented tasks rely upon "know-what" [23] or declarative knowledge [41]. In contrast, process-oriented tasks rely on "know-how" [23] or procedural knowledge

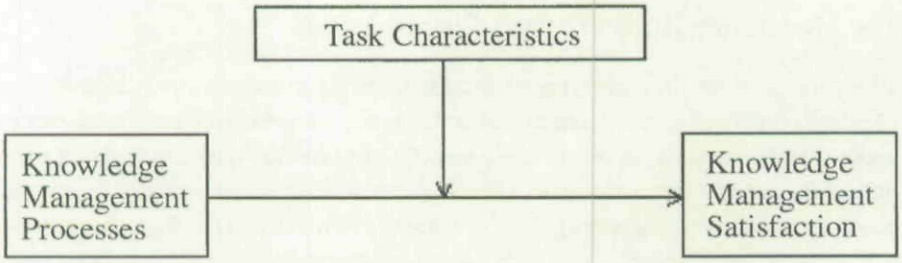

Figure 1. The Basic Research Model

[41]. Moreover, "know-what" and "know-how" have been associated with explicit and tacit types of knowledge, respectively. For example, Grant states: "I identify *knowing how* with *tacit knowledge,* and *knowing about* facts and theories with *explicit knowledge*" [17, p. 111].

Therefore, content-oriented tasks are more likely to benefit from externalization and combination, both of which result in explicit knowledge. In contrast, process-oriented tasks are more likely to benefit from socialization and internalization, which produce tacit knowledge.

Task Domain. This dimension distinguishes between focused and broad task domains, which are reflected in the material-based and system-based industries, respectively, discussed by Kusonaki et al. [24]. Subunits performing focused tasks have low task variability but greater specialization, while subunits performing broad tasks have greater task variability and greater need for working with other subunits within the organization [47].

Performing tasks that are *focused* in domain primarily requires the knowledge directly available to the individuals within the subunit. These tasks rely mainly on distinctive units of knowledge, such as "functional knowledge embodied in a specific group of engineers, elemental technologies, information processing devices, databases, and patents" [24]. They often require deep knowledge in a particular area [36], or knowledge that is high in specificity [6]. With internalization (such as when individuals acquire knowledge by observing or by talking to others), as well as with externalization (such as when they try to model their knowledge into analogies, metaphors, or problem-solving systems), the learning processes are personal and individualized [27]. Through externalization, the individual makes the knowledge more agreeable and understandable to others in the group, while through internalization the individual absorbs knowledge held by others in the group [28, 48]. Internalization and externalization are thus fundamental to knowledge management in a focused task domain.

Performing tasks that are *broad* in domain relies mainly on dynamic interaction in which individual units of knowledge are combined and transformed through communication and coordination across different functional groups [24]. The complexity of such broad-scale integration creates greater causal ambiguity, since knowledge is being integrated across multiple groups that may not have a high level of common knowledge [17]. As Nahapiet and Ghoshal suggest, "Significant progress in the cre-

ation of intellectual capital often occurs by bringing together knowledge from disparate sources and disciplines" [29, p. 252]. Socialization and combination processes, both of which help integrate prior knowledge to create new knowledge [31], are therefore appropriate for broad task domain [17]. When the areas of knowledge being integrated are explicit, combination can help produce new explicit knowledge, whereas when the areas of knowledge being integrated are tacit, socialization processes are more appropriate.

Thus, externalization and internalization processes seem suitable for focused task domain, while combination and socialization processes seem appropriate for broad task domain. Moreover, externalization and combination processes seem appropriate for content-oriented tasks, whereas internalization and socialization processes seem suitable for broad process-oriented tasks. To understand the implications for the effectiveness of knowledge management processes, it is useful to combine the above task attributes, as shown in the matrix in Figure 2, which summarizes our expectations concerning the task attributes for which each of the four knowledge management processes would be most appropriate.

In organizational subunits performing tasks with a process orientation and a focused domain (Figure 2, Cell 1), innovative capability at the individual level would be of the greatest value. Internalization processes, enabling individuals to acquire tacit knowledge from explicit knowledge available to others, would be most useful. According to Choo, "Organizations remember by doing, and action and decision routines become part of the organization's procedural memory" [5, p. 12]. The relevance of internalization for focused, process-oriented tasks is also inherent in organizational routines discussed by Grant:

> Within our knowledge-based view, . . . individuals develop sequential patterns of interaction which permit the integration of their specialized knowledge . . . This coordination relies heavily upon informal procedures in the form of commonly-understood roles and interactions established through training and constant repetition. [16, p. 379]

A senior employee at the International Space Station Hardware Integration Office also seemed to agree: "There is some knowledge that comes from experience, and this knowledge does not get written down, so sometimes to capture this knowledge we would have someone training another person." We therefore propose the following contingency hypothesis.

> *H5: Compared to other organizational subunits, internalization process has a greater affect on perceived knowledge satisfaction in organizational subunits performing focused, process-oriented tasks.*

In organizational subunits performing focused, content-oriented tasks (Figure 2, Cell 2), explicit, objectified knowledge, or "conscious knowledge" [43] is needed rather than tacit or "automatic knowledge" [43]. It is therefore essential to convert the employees' tacit knowledge into an explicit form, so that other individuals within the subunit can also utilize it to address similar problems [16]. Externalization through, for

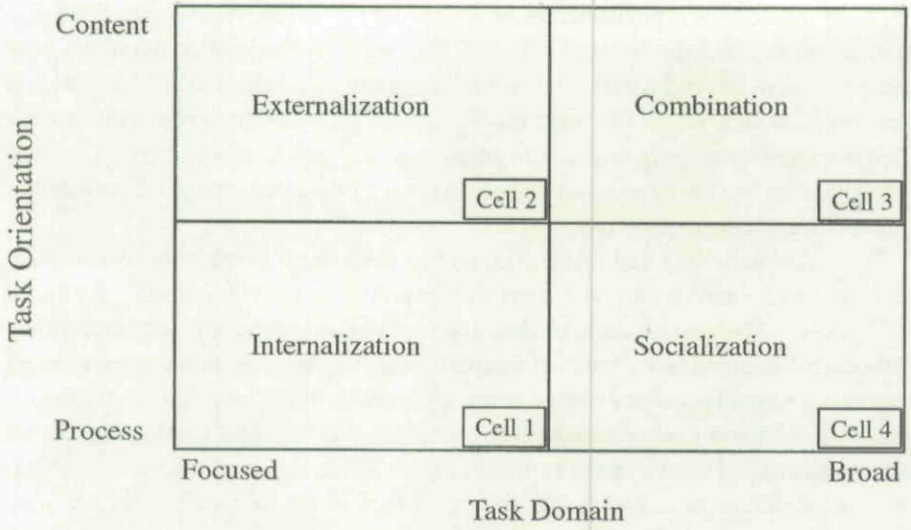

Figure 2. Expected Appropriateness of Knowledge Management Processes

example, models, prototypes, decision support systems that capture individuals' tacit knowledge [31] would therefore play a critical role in such organizational subunits.

H6: Compared to other organizational subunits, externalization process has a greater affect on perceived knowledge satisfaction in organizational subunits performing focused, content-oriented tasks.

In subunits performing broad, content-oriented tasks (Figure 2, Cell 3), the need to share "know-what," or more explicit knowledge across large number of individuals and groups may be best addressed by combination processes. Under these circumstances, it is important to extend existing capabilities to encompass additional types of explicit knowledge and reconfigure existing knowledge into new types of capability. There is consequently greater emphasis on "architectural knowledge" [11] or the integration of knowledge across disciplinary and organizational boundaries. This can be best achieved through combination, which helps integrate explicit knowledge of individuals and produce knowledge that transcends multiple groups [32]. For example, repositories of information, best practices, and lessons learned can help an organizational subunit obtain explicit knowledge from other parts of the organization [10, 45].

H7: Compared to other organizational subunits, combination process has a greater effect on perceived knowledge satisfaction in organizational subunits performing broad, content-oriented tasks.

Finally, organizational subunits performing broad, process-oriented tasks (Figure 2, Cell 4) need to integrate multiple streams of knowledge. This limits the possibility of common knowledge, especially since the need here is for "know-how" and tacit knowledge acquired through personal experience [7]. Moreover, tacit knowledge is often difficult to transfer or "sticky" [49]. Sharing it requires a "common perspec-

tive," which can only be obtained through socialization [31]. There is also evidence that socialization enables using weak ties to help bridge across a diverse pool of people [8]. In a study of two new biotechnology firms, Liebeskind and colleagues found that "social networks contributed to the *integration of knowledge*" [26, p. 439, emphasis in original].

> *H8: Compared to other organizational subunits, socialization process has a greater affect on perceived knowledge satisfaction in organizational subunits performing broad, process-oriented tasks.*

Figure 3 presents the detailed research hypotheses, showing the universalistic hypotheses (H1 through H4) concerning the effects of the knowledge management processes on perceived knowledge satisfaction, as well as the contingency hypotheses (H5 through H8) concerning the way in which these effects are moderated by the two task characteristics.

The Empirical Study

THE EMPIRICAL STUDY WAS CONDUCTED IN TWO MAJOR PHASES. Phase 1 involved a qualitative investigation to understand the tasks performed and knowledge used at various directorates of KSC. This study was conducted in early 1998 and a report was submitted to KSC in August 1998. Phase 2 involved the use of quantitative questionnaire data to test the research hypotheses. This survey was administered at KSC in May 1999. Some key assumptions underlying the analysis in Phase 2 were later validated in two interviews, conducted as a part of a three-day visit to KSC in October 2000. The next two subsections describe the methods and results from the two Phases in detail.

Qualitative Investigation

Methods. This phase was intended to identify the important knowledge areas for KSC and the knowledge management processes that are currently being used. For this purpose, a series of group interviews were conducted. These interviews, conducted between February and April 1998, obtained inputs from 61 individuals at various levels in 9 groups: Administration Office (8 individuals), International Space Station Hardware Integration Office (3 individuals), Biomedical Office (4 individuals), Shuttle Processing Directorate (12 individuals), Payload Processing Directorate (14 individuals), Engineering Development Directorate (8 individuals), Safety and Mission Assurance Directorate (6 individuals), Public Affairs Office (4 individuals), and KSC's Chief Information Office (2 individuals).

Prior to the interviews, the interviewees received a package designed to familiarize them with knowledge management within their subunit. They were asked to review the material in preparation for the upcoming meeting and to reflect upon the following topics:

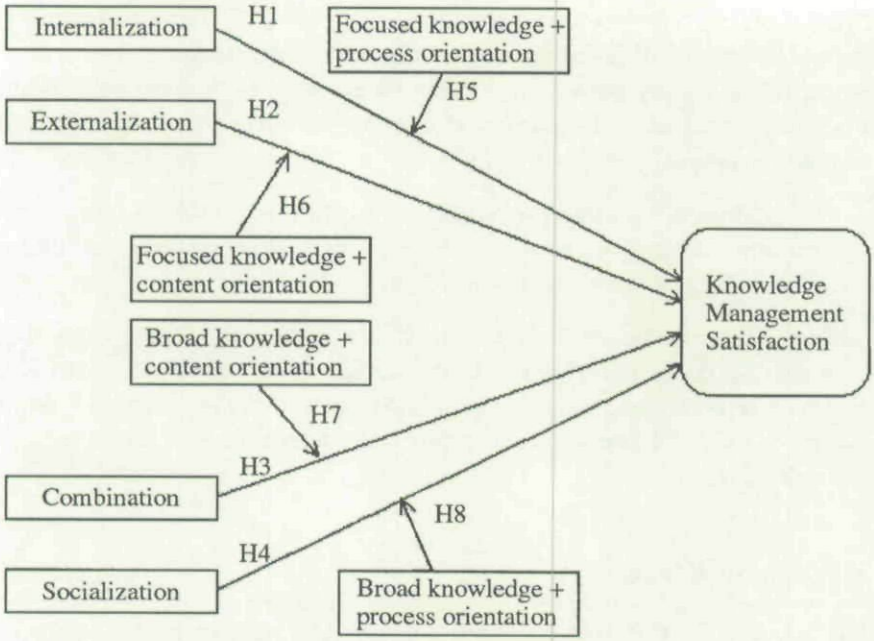

Figure 3. Detailed Research Model

1. What is the role of this directorate/office? What kinds of tasks are performed here?
2. Who/what do you consider to be the best source(s) of knowledge within your organization?
3. Why is this knowledge so important?
4. Who/what uses this knowledge?
5. What knowledge is either created or absorbed in such areas as Product Development, Research and Development, Marketing, and so on.
6. For each of the above areas, what source of knowledge is used?
7. How is this knowledge captured? Disseminated? Accessed?
8. For each of the above areas, who/what uses this knowledge? How do they access this knowledge?

During each interview, three broad steps were followed. First, the specific types of knowledge and their internal or external sources and uses were identified. Next, we identified the particular KM needs for each group. Finally, the interviews were used to identify the tools currently used and to brainstorm possible enhancements in knowledge management.

Following the completion of the interviews, both authors examined the notes and transcripts to prepare for the next phase. A detailed report was written and submitted to KSC.

Results. Table 1 summarizes the functional descriptions of each of the eight organizational subunits at KSC that participated in the second phase of the study. The

Table 1. Partial Justification for the Classification of KSC Directorates and Offices

Subunit[a]	Description	Classification and Rationale
Biomedical Office	Provides medical, environmental, science, and engineering expertise and analytical laboratory support to activities across the center and to the conduct of life sciences operations in ecological monitoring and life sciences life experiment programs.	**Process-oriented:** Its responsibilities include the processes involved in experimentation and scientific analysis. It focuses on ways of improving the effectiveness and efficiency of these processes. **Broad task domain:** It has considerable interactions with the other subunits and performs a variety of different tasks depending on the payload.
Engineering Development Directorate	Focused on advanced engineering and applied research and development with ground and flight systems, more specifically the planning, development, and application of advanced technologies at KSC.	**Process-oriented:** Its responsibilities include planning, development, and use of new technologies. It focuses on how to best perform these processes. **Broad task domain:** It has considerable interactions with the other subunits and performs a large variety of tasks, as mentioned above.
Payload Processing Directorate	Responsible for overall payload integration, configuration control, contract, and budget management, it includes several groups, most important being customer support (focusing on the identification of launch-site needs, engineering requirements, and documentation requirements), on-site integration (for establishing the criteria that need to be met when integrating the payload onto the shuttle), and outreach (to identify the future needs of external customers).	**Broad task domain:** It has considerable interactions with the other subunits for identifying current and future needs. It also includes several groups, which perform a variety of tasks, including customer support (focusing on identification of launch-site needs, engineering requirements, and documentation requirements), on-site integration (for establishing the criteria that need to be met when integrating the payload onto the shuttle), and outreach (to identify the future customer needs). **Content-oriented:** As mentioned above, it focuses on identifying a number of content areas, including criteria, needs, and requirements.

(Continued)

Table 1. Partial Justification for the Classification of KSC Directorates and Offices (Continued)

Subunit[a]	Description	Classification and Rationale
Public Affairs Office	Responsible for public information, media relations, aerospace education for grades K–12, university affairs, Manned Flight Awareness activities, community relations, tours and briefings of distinguished visitors, guest activities for launches, landings, and special events, and the KSC Visitor Complex, Spaceport U.S.A.	**Broad task domain:** As the description indicates, this subunit focuses on the dissemination of information about numerous different matters. This information is obtained from a variety of subunits at KSC and is distributed to several different external groups. **Content-oriented:** As indicated above and to the left, this subunit focuses on information about what KSC does and plans to do, rather than how KSC does these things. It seeks to provide more timely and appropriate information to external entities.
Safety and Mission Assurance Directorate	It focuses on a specific set of requirements that need to be met for industrial safety (such as the list of hazardous materials to be avoided) and checklists of items that need to be conformed with.	**Content-oriented:** It focuses on specific requirements that need to be met for industrial safety, such as the hazardous materials to be avoided and the items that need to be conformed with. **Focused task domain:** It performs a relatively similar set of tasks for ensuring the safety of various tasks, although those tasks are rather demanding in nature and require considerable knowledge.

Shuttle Processing Directorate	Provides preflight, launch, landing, and recovery services for KSC. It has a processing team composed of two second-line directorates: the Shuttle Vehicle Engineering Directorate and the Ground Systems Directorate.	**Process-oriented:** Its responsibilities include planning, development, and use of new technologies. It focuses on how to best perform the processes associated with the shuttle launch and landing. **Focused task domain:** It performs a relatively similar set of tasks to facilitate launch and landing, although those tasks are rather demanding in nature and require considerable knowledge. Moreover, it has most of the needed skills internally, requiring limited interaction with the other subunits.
International Space Station Hardware Integration Office	Responsible for the management and integration of the overall ground process for all U.S. launched elements, from Assembly and Checkout through Verification and Launch. This office has a highly technical focus, and it provides consulting to contractors.	**Process-oriented:** It concentrates on the process by which the launched elements would be integrated and looks for ways to do this in the best possible fashion for each launch. **Focused task domain:** As mentioned above, it concentrates on a relatively similar set of tasks to facilitate launch and landing, even though those tasks are rather demanding in nature and require considerable skills and knowledge. It interacts with external organizations, but the interaction proceeds in a generally similar fashion in most cases.

These directorates and offices existed at the time of the survey (early 1999). They were later affected by the KSC 2000 reorganization in 2000.

[a] The Administration Office were included in the survey but dropped from the hypothesis tests due to some ambiguity in mapping it on the task matrix, as discussed in the paper. This office is responsible for contractor industrial relations, the civil service workforce and position management program, the civil service personnel program, internal control activities, continual improvement activities, and management overview and coordination of information services.

qualitative data was used to examine these subunits in terms of task orientation and task domain. The two authors did this independently. When they later discussed their conclusions, they found no disagreement.

Based on the analysis of the subunits in terms of task orientation and using the descriptions of process and content task orientation provided by Pisano [36], Engineering Development and Shuttle Processing Directorates and the International Space Station Hardware Integration Office were clearly viewed as process-oriented. These subunits' responsibilities center around engineering, applied research and development, and engineering management. The Biomedical Office was also considered as process-oriented, since its functional responsibility centers around experimentation and scientific analysis. In contrast, the other subunits (including the Safety and Mission Assurance and Payload Processing Directorates and the Public Affairs and Administration offices) were believed to focus more on "what to do" kind of issues and were therefore classified as content-oriented. The last column of Table 1 summarizes some of the rationale for the way we classified each subunit.

Next, the subunits were characterized on the basis of task domain, using the definitions for focused and broad domains. The International Space Station Hardware Integration Office, the Shuttle Processing Directorate, and the Safety and Mission Assurance Directorate were considered to perform a limited number of complicated tasks, requiring highly specialized and deep knowledge that is local to them, and were therefore classified as focused in task domain. In contrast, the organizational subunits at KSC that perform a greater variety of dissimilar tasks, requiring considerable interactions with the other subunits, were classified as being broad in knowledge domain. They included the Biomedical, Administration, and Public Affairs offices, and the Engineering Development and Payload Processing Directorates.

Thus, based on the insights from the qualitative study and the theoretical expectations, the organizational subunits at KSC were placed in the two-dimensional matrix involving task orientation and task domain as shown in Figure 4. These classifications were later used in the quantitative part of the study. However, in order to further establish the validity of our classification of the KSC subunits into the four cells, we conducted two detailed interviews on this aspect during a visit to KSC in October 2000.[1] During the first interview, we spoke to one executive at KSC for about an hour and a half and asked her to classify the eight subunits first based on the content/process dimension and then based on the focused/broad dimension. Later, we met with another executive of KSC for three and a half hours. In this meeting, we went over the paper with her, explaining the four-cell matrix in quite some detail. We then requested her to examine our mapping of the eight subunits into the four cells. We discussed each subunit in some detail. There were some concerns about the Administration Office, as the first interviewee classified it in Cell 4 (unlike our perception of it belonging in Cell 3), whereas the second interviewee classified it in Cell 1. Therefore, we decided to exclude the Administration Office from the analysis for testing the hypotheses. However, based on the two interviews, and especially the second one, which was very detailed, we feel quite confident about the mapping of the other seven subunits. After developing a good understanding of the four-cell matrix, the second

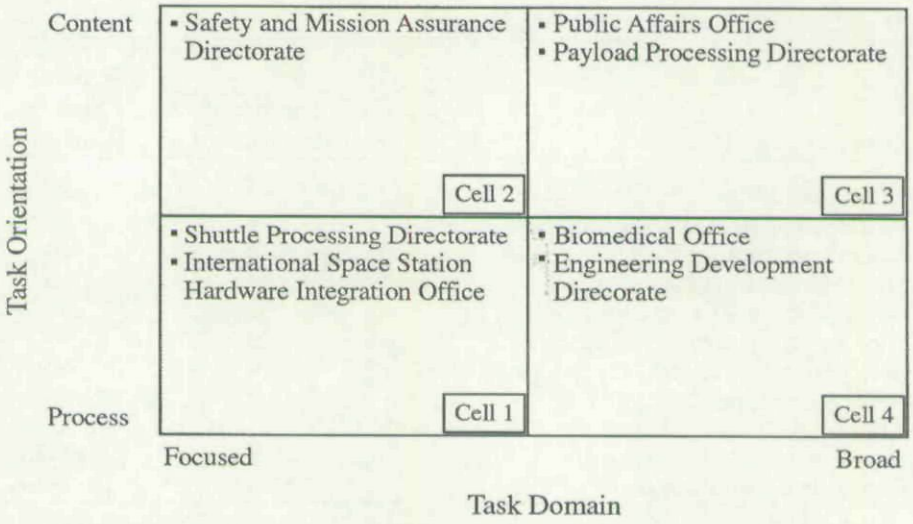

Figure 4. Organizational Subunits at the Kennedy Space Center. The placement of the directorates and offices in this matrix was determined based on Phase 1 (i.e., the qualitative study) and was later validated during two detailed interviews in October 2000. Based on these interviews, one office Administration, which was mapped by the authors as belonging to Cell 3, was dropped from further analysis due to ambiguity about its mapping on this matrix.

interviewee strongly agreed with our classification of these seven subunits. Table 1 summarizes the rationale underlying the classification of each subunit.

Questionnaire Survey

Methods

Questionnaire development and administration. Based on the prior literature on knowledge management and the findings of the first phase, we developed a questionnaire to empirically test the research hypotheses. Feedback on the initial questionnaire was obtained from three employees of KSC's Chief Information Officer's (CIO) office (this group was not used for the actual survey). Minor modifications were made based on the suggestions received.

KSC's Administration Office helped conduct the survey at eight KSC subunits. We provided 250 questionnaires to the secretary in the Administration Office, with the number of questionnaires per group varying from 20 for small groups to 40 for the large ones. Following a discussion between the Deputy Center Director and the various Administrative Officers, 200 questionnaires were distributed to potential respondents. Table 2 provides the number of questionnaires distributed as well as the number of responses received in each group. A letter from the Deputy Center Director accompanied the surveys, which helped to increase the response rate. A total of 159 completed surveys was received, representing a 79.5 percent response rate.[2] The

Table 2. Some Characteristics of the Sample

Directorate or Office[a]	Number of Respondents	Number of Surveys Distributed
Administration Office[b]	12	15
Space Station Hardware Integration Office	22	25
Biomedical Office	15	20
Shuttle Processing Directorate	14	20
Payload Processing Directorate	38	40
Engineering Development Directorate	28	35
Safety and Mission Assurance Directorate	24	30
Public Affairs Office	6	15
Respondent Characteristics	**Mean**	**Standard Deviation**
Total experience at KSC	15.35	6.93
Number of directorates or offices previously served in	1.20	1.17
Hierarchical Level	**Frequency**	**Percent**
1. Director of a Directorate	1	0.6
2. Deputy Director of a Directorate	18	11.3
3. Chief, Ground Systems Division	43	27.0
4. Personal Management Specialist	77	48.4
5. Systems Engineer	14	8.8
Missing	6	3.8
Total	159	100

[a] These directorates and offices existed at the time of the survey (early 1999). They were later affected by the KSC 2000 reorganization in 2000.

[b] Data from the Administration Office was not used to test the hypothesis due to some ambiguity in mapping it on the task matrix, as discussed in the paper.

response rates differed across groups, being the lowest at Public Affairs and the highest at Payload Processing. However, the overall differences across groups were not significant ($\chi^2 = 4.66$, degrees of freedom = 7, not significant at the 0.10 level).

Table 2 also summarizes other characteristics of the sample. The respondents were generally quite experienced (average experience of 15.35 years). They usually worked in one or more other groups at KSC prior to joining their current group, which may be expected to increase their awareness of knowledge management in areas of KSC beyond their current group. Sixty-two of the respondents were very senior, being at the level of a Director, Deputy Director, or a Chief of a Division, while the remaining 91 respondents who identified their levels were at lower to middle management levels. Overall, the sample of respondents seems to be quite diverse, representing various hierarchical levels, experiences, and groups.

Measures. Phase 1 of the study led to the identification of 37 knowledge management tools currently used at KSC. These tools, along with some additional tools that were not mentioned in the interviews but have been highlighted in the literature [10, 35], were used to prepare a list of tools. These were examined by the two authors for possible overlaps. We tried to identify a number of tools that support each knowledge management process and also decided to limit the number of tools to 25 to prevent the questionnaire from becoming excessively demanding. A question (on a five-point scale) was included to evaluate the use of each of these tools. Exploratory factor analysis found 6 items to load on multiple dimensions.[3] The remaining 19 items produced 4 factors, each with the expected set of items. The reliabilities of the measures for internalization, externalization, combination, and socialization processes are 0.74, 0.85, 0.80, and 0.66, respectively. Table 3 provides some illustrative remarks from the literature supporting the use of items used to measure each knowledge management process.

Confirmatory factor analyses were then conducted using LISREL 7.20 to assess the overall measurement models involving the 19 indicators of knowledge management processes. Appendix A provides the results of this analysis. We first tested the unconstrained model, with each item loading only on the process it was intended to measure and with the correlations among the four latent constructs made free. As shown in the bottom frame of Appendix A, this model performed satisfactorily, with a χ^2/d.f. ratio of 0.99, a p-value of 0.514, Goodness of Fit Index (GFI) and Normed Fit Index (NFI) exceeding 0.90,[4] the Adjusted Goodness of Fit Index (AGFI, which adjusts GFI for degrees of freedom) of 0.88, and a root mean square residual (RMSR) of 0.056. To examine the discriminant validity of the four knowledge management processes, we examine seven alternative constrained models. For each alternative model, chi-square differences from the unconstrained model were examined to evaluate discriminant validities [2]. The first six models combined a pair of latent constructs, while leaving the remaining two constructs separate. The last model combined all four latent constructs. All these models produced large and significant ($p \leq 0.001$) increases in χ^2, indicating that the four processes should be considered distinct. The 19 items measuring these processes are given in the top frame of Appendix A along with their loadings on the corresponding processes. All the λ's are large and significant ($p \leq 0.001$), providing further support to the measures. Thus, careful consideration of prior literature, followed by a series of statistical tests including exploratory factor analysis, reliabilities, and comparative confirmatory factor analyses, led to the development of theoretically and psychometrically strong measurement scales for the four knowledge management processes [15].

Eleven questions were used to measure perceived knowledge satisfaction. Exploratory factor analysis provided strong support for this measure, which was further validated by a reliability of 0.92. Appendix B provides further details about this measure, including the 11 items.

Results. Table 4 gives the means, standard deviations, reliabilities (standardized Cronbach alphas), and zero-order correlations among the research variables. Three control variables—the number of directorates and offices the respondent had previously

Table 3. Partial Justification for Items Measuring Knowledge Management Processes

Knowledge Management Activity	Illustrative Quote Justifying the Activity Classification
Socialization	
Employee rotation across areas	**Rotation** helps employees understand the business from a multiplicity of perspectives. This makes organizational knowledge more "fluid" and easier to put into practice. [31, p. 7]
Brainstorming retreats or camps	The first example of socialization comes from Honda, which set up "**brainstorming camps**" *(tama dashi kai)*—informal meetings for detailed discussions to solve difficult problems in development projects. [33, p. 63]
Cooperative projects across directorates	A self-organizing **team, in which members from various functional departments work together** to achieve a common goal. This example shows that the first phase of the organizational knowledge creation process corresponds to socialization. [33, p. 85]
The use of apprentices and mentors to transfer knowledge	One important point to note here is that an individual can acquire tacit knowledge without language. **Apprentices work with their mentors** and learn craftsmanship not through language. [31, p. 19]
Internalization	
Learning by observation	Exercising ba supports the internalization phase. Exercising ba facilitates the conversion of explicit knowledge to tacit knowledge. Focused training with senior mentors and colleagues consists primarily of continued exercises that stress certain patterns and working out of such patterns. [32, p. 46]
Learning by doing	The internalization of newly created knowledge is the conversion of explicit knowledge into the organization's tacit knowledge. . . . **Learning-by-doing,** training, and exercises allow the individual to access the knowledge realm of the group and the entire organization. [32, p. 45]

On-the-job training	The internalization of newly created knowledge is the conversion of explicit knowledge into the organization's tacit knowledge. . . . Rather than teaching based on analysis, learning by continuous self-refinement through OJT [**on-the-job-training**] or peripheral and active participations is stressed. [32, p. 47]
Face-to-face meetings	The product divisions also frequently send their new-product development people to the Answer Center to chat with the telephone operators or the 12 specialists, thereby "re-experiencing" their experiences. [33, p. 69] Some believe that the most valuable and untapped knowledge is tacit . . . they seek to encourage and facilitate conversations and unplanned or chance encounters. This is why designating physical meeting spaces is on their agenda. [13, p. 32]
Combination	
Databases Repositories of information, best practices, and lessons learned	Combination is a process of systemizing concepts into a knowledge system. . . . **Reconfiguration of existing information** through sorting, adding, combining, and categorizing of explicit knowledge (as conducted in **computer databases**) can lead to new knowledge. [33, p. 67]
Web-based access to data	The combination of explicit knowledge is most efficiently supported in collaborative environments utilizing information technology. The use of **on-line networks** . . . **and database** . . . has been growing rapidly over the last decade, enhancing this conversion process. [32, p. 46]
Web pages (Intranet and Internet)	Combination is a process of systemizing concepts into a knowledge system . . . Individuals exchange and combine knowledge through such media as . . . **computerized communication networks.** [33, p. 67]
Externalization	
Capture and transfer of experts' knowledge	In practice, externalization is supported by two factors . . . the second factor involves translating the **tacit knowledge of customers or experts** into readily understandable forms. [32, p. 44]
Chat groups/Web-based discussion groups	In the projects we studied, when firms wanted to extract tacit knowledge from employees for a repository, they opted for some sort of **community-based electronic discussion.** [10, p. 147]

(Continued)

Table 3. Partial Justification for Items Measuring Knowledge Management Processes (Continued)

Knowledge Management Activity	Illustrative Quote Justifying the Activity Classification
Externalization (continued)	
A problem-solving system based on a technology like case-based reasoning Decision support systems	In practice, externalization is supported by two factors . . . the second involves translating the tacit knowledge of . . . experts . . . may require **deductive/inductive reasoning.** [32, p. 44] Finally, the last step in the knowledge creation process is to create **an actual model.** A model is far more immediately conceivable than a metaphor or an analogy. [31, p. 6]
Groupware and other team collaboration tools	In practice, externalization is supported by two factors . . . one is the articulation of tacit knowledge . . . **dialogue, "listening and contributing to the benefit of all participants"** strongly supports externalization. [32, p. 44]
Modeling based on analogies	Externalization is therefore often driven by metaphor and/or analogy. Using an attractive metaphor and/or **analogy** is highly effective in fostering direct commitment to the creative process. [33, p. 65]
Pointers to expertise (skills "yellow pages")	In practice, externalization is supported by two key factors. The second factor involves translating the tacit knowledge of customers or **experts** into readily understandable forms. . . . the translation of the highly personal or highly professional knowledge of customers or specialists into explicit forms that are easy to understand. [32, p. 44]

Table 4. Descriptive Statistics and Inter-Correlations for the Research Variables

		Mean[a]	S.D.	No. of Items	Reliability[b]	Correlation Coefficients[c]						
						PRVDIR	SENIOR	EXPER	PROINT	PROEXT	PROCOM	PROSOC
No. of Previous Directories/ Offices	PRVDIR	1.20	1.16	1	—							
Seniority	SENIOR	1.47	0.83	1	—	0.12						
Experience (years)	EXPER	15.34	6.86	1	—	0.31***	0.20*					
Internalization	PROINT	4.13	0.70	4	0.74	0.04	0.04	0.14#				
Externalization	PROEXT	1.94	0.71	7	0.85	–0.02	–0.05	–0.05	0.04			
Combination	PROCOM	3.24	0.86	4	0.80	0.09	0.07	0.06	0.30***	0.47***		
Socialization	PROSOC	2.70	0.77	4	0.66	0.02	0.08	0.01	0.31***	0.41***	0.38***	
Knowledge satisfaction	DEPKNO	3.13	0.75	11	0.92	–0.01	–0.08	0.13#	0.32***	0.42***	0.51***	0.42***

Experience was measured in years, seniority as 6-the number of hierarchical levels below the Director of KSC. Except for these two control variables as well as the third control variable, the number of previous directorates, all other variables were measured on a 5-point scale.

[a] Listwise deletion (n = 139) was used. These correlation results are based on data including the responses from the Administration Office, which were excluded for the regression analysis.

[b] For multi-item measures, the reliabilities were measured using standardized Cronbach alphas.

[c] The significance of the correlation coefficients is indicated as follows: *** $p \leq 0.001$; ** $p \leq 0.01$; * $p \leq 0.05$ # $p \leq 0.10$.

worked in, the seniority of the respondent, and the respondent's experience (in years)—were used in the study and are included in this table.

It may be noted from Table 4 that KSC makes considerable use of internalization (mean of 4.13, with all means mentioned in this paragraph being on a five-point scale) but little use of externalization (mean of 1.94). Combination and socialization are both used to a moderate extent with means of 3.24 and 2.70, respectively. Perceived knowledge satisfaction is also moderate with a mean of 3.13. With the exception of the correlation between externalization and internalization, all the correlations among the four knowledge management processes are statistically significant ($p \leq 0.001$). Moreover, all four knowledge management processes have statistically significant correlations ($p \leq 0.001$) with perceived knowledge satisfaction.

To test the hypotheses, we used hierarchical regression analysis with the perceived knowledge satisfaction as the dependent variable. We first examined the relationships in the entire sample. The three control variables were entered first, followed by the main effects of the four knowledge management processes (testing Hypotheses 1 through 4), and then the interaction terms corresponding to Hypotheses 5 through 8. This procedure eliminated the main effect of each knowledge management process prior to our examining the interaction effects [44]. Moreover, entering all the interaction terms simultaneously controls for possible multicollinearity among the variables. Evidence of moderation is present when the interaction terms account for significant residual variance in the dependent variable. Therefore, the changes in R^2 and the F-statistic were examined for each step. Throughout our analysis, we paid attention to the standardized beta coefficients if the F-statistic for that hierarchical step was significant ($p \leq 0.10$).[5]

As shown in Table 5, the control variables, when entered as a set in Step 1, do not explain a statistically significant (at $p \leq 0.10$ level) proportion of the variance in perceived knowledge satisfaction. The four knowledge management processes, entered in Step 2, do produce a significant ($p \leq 0.001$) increase of 0.365 in R^2. All four knowledge management processes have significant standardized betas in this step at $p \leq 0.05$ or better.

When the interaction terms are introduced in Step 3, a significant ($p \leq 0.10$) increase in R^2 results. As expected, some changes occur in the standardized betas of control variables and the main effects of the knowledge management processes. More senior ($p \leq 0.05$) and less experienced ($p \leq 0.05$) respondents apparently have lower perceived knowledge satisfaction. Moreover, externalization and combination continue to have a significant ($p \leq 0.05$) positive effect, providing support for hypotheses H2 and H3, respectively. However, internalization and socialization no longer significantly affect perceived knowledge satisfaction, and hypotheses H1 and H4, respectively, are thus not supported. The interaction terms involving internalization ($p \leq 0.05$), combination ($p \leq 0.05$), and socialization ($p \leq 0.10$) are also significant, providing support for hypotheses H5, H7, and H8, respectively. But hypothesis H6, concerning the greater impact of externalization in Cell 2, is not supported.

The hypotheses were further tested through regressions within each of the four cells. As may be seen from Table 6, which summarizes the results, the control variables did not explain a significant portion of the variance in perceived knowledge

Table 5. The Overall Effects of Knowledge Management Processes

	Step 1	Step 2	Step 3
Control Variables[a]			
No. of previous directorates	–0.06	–0.09	–0.06
Seniority	–0.10	–0.12#	–0.14*
Experience	0.16#	0.14#	0.14*
Knowledge Management Processes			
Internalization		0.15*	0.07
Externalization		0.18*	0.20*
Combination		0.34***	0.24*
Socialization		0.15*	0.07
Interaction Effects			
Internalization X Dummy for Cell 1			0.37*
Externalization X Dummy for Cell 2			0.17
Combination X Dummy for Cell 3			0.48*
Socialization X Dummy for Cell 4			0.33#
Equation			
ΔR^2	0.026	0.365	0.036
R^2	0.026	0.391	0.432
ΔF	1.12	18.16***	2.27#
F	1.12	11.12***	8.20***
n		129	

Based on multiple linear regressions. The variables were entered in the order shown, from Step 1 to Step 3.

These results are produced while excluding the data from the Administration Office. However, the two authors had mapped the Administration Office on Cell 3, and the results consistent with the above were obtained when the analysis was repeated with the responses from the Administration Office being included in Cell 3.

[a] The standardized betas are given for each variable included in each step. Significance levels are indicated as follows: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, # $p < 0.10$.

satisfaction in Step 1 in any of the four cells. The four knowledge management processes, on the other hand, explain a significant proportion of the variance in perceived knowledge satisfaction in Step 2 in three of the four cells (all except Cell 2, i.e., focused, content-oriented tasks, thereby indicating a lack of support for H6). In each of these three cells, the hypothesized knowledge management process had a significant effect—internalization in Cell 1 ($p \leq 0.05$), supporting hypothesis H5; combination in Cell 3 ($p \leq 0.01$), supporting hypothesis H7; and socialization in Cell 4 ($p \leq 0.05$), supporting hypothesis H8. These results for hypotheses H5 through H8 (including the lack of support for H6) are consistent with those reported above, based on interaction terms in regressions in the entire sample. Moreover, outside of externalization having a significant effect ($p \leq 0.10$) in Cell 1, none of the knowledge management processes significantly affects perceived knowledge satisfaction in a cell other than the one they were expected to impact. Thus, there is strong support for the contingency framework suggested in this paper for the appropriateness of the four knowledge management processes.

Table 6. The Effects of Knowledge Management Processes in Each Cell

	Cell 1 (Focused, process)		Cell 2 (Focused, content)		Cell 3[a] (Broad, content)		Cell 4 (Broad, process)	
	Step 1	Step 2	Step 1	Step 2	Step 1	Step 2	Step 1	Step 2
Control Variables[b]								
No. of previous directorates	0.22	–0.02	–0.11	–0.18	–0.02	0.11	–0.30#	–0.25#
Seniority	–0.05	0.32	0.05	–0.35	–0.37*	–0.29*	–0.08	–0.15
Experience	–0.01	0.11	0.26	0.47	0.07	0.13	0.30#	0.14
Knowledge Management Processes								
Internalization		0.43*[c]		–0.18		0.09		0.05
Externalization		0.44#		0.53		0.09		0.19
Combination		0.21		0.15		0.56**		0.21
Socialization		–0.11		0.07		–0.11		0.39*
Equation								
ΔR^2	0.042	0.425	0.048	0.376	0.126	0.335	0.143	0.427
R^2	0.042	0.467	0.048	0.424	0.126	0.461	0.143	0.570
ΔF	0.38	4.39**	0.27	1.96	1.68	4.81**	2.00	7.96***
F	0.38	2.76*	0.27	1.26	1.68	3.78**	2.00	6.07***
n	30	20	39	40				

Based on multiple linear regressions. The variables were entered in the order shown, from Step 1 to Step 2.

[a] These results are based while excluding the data from Administration Office. However, the two authors had mapped the Administration Office on Cell 3, and the results consistent with the above were obtained when the analysis was repeated while including responses from the Administration Office in Cell 3.

[b] The standardized betas are given for each variable included in each step. Significance levels are indicated thus: *** $p \leq 0.001$, ** $p \leq 0.01$, * $p \leq 0.05$, # $p \leq 0.10$.

[c] The standardized betas for the knowledge management processes hypothesized to impact knowledge management satisfaction in each cell are given in bold.

Conclusions and Discussion

THIS PAPER BEGAN WITH TWO SIMPLE QUESTIONS: (1) How does the use of knowledge management processes affect knowledge management effectiveness? and (2) How does the effectiveness of these processes change depending on the tasks performed within the organizational subunit? To address these questions, we drew upon Nonaka's [31] internalization, externalization, combination, and socialization processes, and developed empirical measures for evaluating the extent to which each process is used. Four hypotheses (H1 through H4) linking the use of these four processes to perceived knowledge satisfaction were proposed. We also developed a contingency framework, involving two characteristics of the task performed by the organizational subunit, namely process or content task orientation, and focused or broad task domain. The four cells of the matrix combining these two dimensions were then related to the four knowledge management processes through four contingency hypotheses, with internalization, externalization, combination, and socialization processes being considered appropriate for focused, content-oriented tasks (H5), focused, process-oriented tasks (H6), broad, process-oriented tasks (H7), and broad, content-oriented tasks (H8), respectively.

The research hypotheses, developed based on prior theory, were empirically examined in one organization, NASA-KSC. Following a detailed qualitative investigation, we collected empirical data from 159 individuals across 8 subunits of NASA-KSC. Exploratory factor analysis and reliabilities were used to test the psychometric properties of our measures of knowledge management processes and knowledge satisfaction. Structural equation modeling techniques were used to further test the measurement model for the knowledge management processes. Hierarchical regression analyses were used to test the hypotheses.

We now examine our overall findings and their implications for practice, while distancing ourselves from the complexities of the data and the analytical procedures. Upon testing the universalistic hypotheses (H1 through H4), we found combination and externalization processes, but not internalization and socialization processes, to affect perceived knowledge satisfaction. Thus, both of the knowledge management processes that provide explicit knowledge—that is, combination processes, which help integrate several codified areas of knowledge, and externalization processes, which help explicate tacit knowledge—contribute to knowledge satisfaction. On the other hand, internalization and socialization processes, which focus primarily on more tacit knowledge, do not contribute to knowledge satisfaction. These findings should be useful to managers in organizations resembling KSC, that is, organizations with an orientation toward science and engineering.

The empirical data provided considerable support to the contingency framework we proposed for the appropriateness of the four knowledge management processes. All the knowledge management processes other than externalization had an impact on perceived knowledge satisfaction in the expected cell. Moreover, with one exception, none of the knowledge management processes significantly affected perceived knowledge satisfaction in a cell other than the one they were expected to have an

impact in. This strong support for the contingency framework has a potentially important implication for practice. It suggests that managers should try to understand the characteristics of their tasks, and then, based on task domain and orientation, identify and develop the knowledge management processes that are most appropriate. This would be a better strategy rather than efforts to develop all four knowledge management processes, especially under limited resource conditions.

Finally, the low use of externalization suggests an area where improvement needs to be made. Although externalization significantly influences perceived knowledge satisfaction, externalization was used to a very low level. In contrast, internalization, which did not seem to impact perceived knowledge satisfaction at an overall level (it does impact perceived knowledge satisfaction within Cell 1), exhibited a high level of usage. This may be because internalization benefits more from traditional learning and pedagogical techniques. Greater efforts are therefore necessary to build tools and techniques that facilitate externalization.

The findings of this study should be considered in the light of its inherent limitations. First, it focused on one large organization. Although this enabled us to examine the research questions with considerable richness in an organization where knowledge is of paramount importance, it limited the generalizability of the results. Like other organizations, KSC has its unique strategic, structural, and cultural attributes, and it remains to be seen whether our results can be generalized to other kind of organizations.

Second, the findings of the paper may be limited by the fact that we mapped the organizational subunits based on qualitative assessments of each subunit's task characteristics. We recognize that quantitative measures of task domain and task orientation might have further enhanced the value of the study. But we did not use such measures because that would have required: (a) the identification of the specific tasks within each subunit; (b) the development of scales to measure task domain and task orientation; and (c) use of those measures for each task within each directorate. Although acknowledging this limitation, we remain confident about our assessments, which are based on interviews with numerous individuals at KSC, and were supported in two interviews specifically focusing on this issue.

Third, our findings are based on self-report data, entailing potential respondent bias (e.g., social desirability effect) or general method variance. However, the fact that the study reported good psychometric properties based on multiple assessments (reliability, exploratory factor analysis, and confirmatory factor analysis) supports the validity of our results.

Finally, like most social science models, ours excludes some potentially important factors. We only considered the knowledge management processes as antecedent variables affecting knowledge satisfaction. To prevent the analysis from being overwhelmingly complex, we did not include other factors affecting knowledge satisfaction. We also relied exclusively on Nonaka's [31] knowledge management processes and did not consider the roles played by organizational routines, directions, and other possible knowledge management processes.

Thus, the above limitations constrain the generalizability of our results to other organizations and contexts. However, we believe that, despite these limitations, this

study makes some valuable contributions to practice and identifies some potentially important directions for future research.

First, further research is needed to test our results, obtained from in-depth investigation of one organization, in a large number of organizations. Such further research may also examine whether our findings apply primarily to engineering-oriented and "knowledge-intensive" organizations [34], such as KSC, or to other organizations as well.

Second, detailed case studies performing each of the four cells may help provide further elaboration of this contingency model and may also produce greater insights into the effects of the four processes on perceived knowledge satisfaction. In other words, this study has contributed to the "know-what" by providing some insights into the effects of various knowledge management processes, but further research is needed to generate the "know-how," that is, the way in which these effects come about.

Third, the measures we have developed for the four knowledge management processes and perceived knowledge satisfaction may be useful in future research on knowledge management. Similar measures should, however, be developed for other relevant constructs, including the use of directions, organizational routines, task domain, and task orientation, as well as the role information technology plays in knowledge management. Moreover, considering the usual limitations of perceptual measures, objective measures of perceived knowledge satisfaction would be useful in future research in this area.

Finally, further research is needed to build on the contingency model developed and tested here. Other knowledge management tools and processes, such as routines and directions, as well as other contingency factors, including industry and product characteristics, and the business strategy and organization structure need to be included in broader, and possibly more general, contingency models of knowledge management.

Acknowledgments: The authors greatly appreciate the comments Varun Grover and an anonymous reviewer provided on an earlier draft of this paper. We thank NASA-KSC and Florida Space Grant Consortium for a research grant (#NAG10-0232) from which this study was partially funded. They are also grateful to James Jennings, Loren Shriver, and Pat Simpkins, who championed this initiative, Shannon Roberts, who provided numerous invaluable suggestions during the course of this study, the large number of KSC employees who participated in this project, and Gregg Buckingham and June Perez for their help during data collection. Research assistance provided by Hector Hartmann, Maria Ray, Jessica Riedel, and Aracelys Rodriguez from the Knowledge Management Lab at FIU is appreciated.

Notes

1. This visit was conducted after the questionnaire survey. During this visit, a total of 13 interviews were conducted with 17 individuals, but only 2 of these interviews focused on the aspects relevant to this paper. Moreover, following the questionnaire survey and before the visit in October 2000, KSC was reorganized, and the number of directorates and offices were reduced from 23 to 13.

2. Six respondents did not provide their titles, and there were some other missing items in some responses. Following listwise deletion, 139 responses were used in the analysis.

3. "Case studies and stories," "Simulations and game playing," "Drawing inferences from trends in historical data," "Development of prototypes," "Learning from prototypes," and "Learning from concept maps and expert system," were dropped as they loaded on multiple dimensions in exploratory factor analysis.

4. NFI indicates the extent to which the hypothesized model improves over the null model, wherein all observed variables are specified as uncorrelated [3].

5. We chose to use a 0.10 significance level as the initial cutoff for interpreting results of the analysis due to the exploratory nature of the research. This liberal approach is often recommended for exploratory research in order to reduce the probability of a Type II error [19, 42].

References

1. Alavi, M., and Leidner, D.E. Knowledge management systems: issues, challenges, and benefits. *Communications of the Association for Information Systems, 1,* 7 (1999), available at cais.aisnet.org/authors.asp?auth=119.

2. Anderson, J.C., and Gerbing, D.W. Structural equation modeling in practice: a review and recommended two-step approach. *Psychological Bulletin, 103,* 3 (1988), 411–423.

3. Bentler, P.M., and Bonnett, D.G. Significance tests and goodness-of-fit in the analysis of covariance structures. *Psychological Bulletin, 88,* 3 (November 1980), 588–606.

4. Boland, R.J., and Tenkasi, R.V. Perspective making and perspective taking in communities of knowing. *Organization Science, 6,* 4 (1995), 350–372.

5. Choo, C.W. *The Knowing Organization: How Organizations Use Information to Construct Meaning, Create Knowledge, and Make Decisions.* New York: Oxford University Press, 1998.

6. Choudhury, V., and Sampler, J. Information specificity and environmental scanning: an economic perspective. *MIS Quarterly, 21,* 1 (1997), 25–53.

7. Conner, K.R., and Prahalad, C.K. A resource-based theory of the firm: knowledge versus opportunism. *Organization Science, 7,* 5 (1996), 477–501.

8. Constant, D.; Sproull, L.; and Kiesler, S. The kindness of strangers: the usefulness of electronic weak ties for technical advice. *Organization Science, 7,* 2 (1996), 119–135.

9. Davenport, T.H., and Hansen, M.T. Knowledge management at Andersen Consulting. Case No. 9-499-032. Boston: Harvard Business School, 1999.

10. Davenport, T.H., and Prusak, L. *Working Knowledge: How Organizations Manage What They Know.* Boston: Harvard Business School Press, 1998.

11. de Boer, M. Managing organizational knowledge integration in the emerging multimedia complex. *Journal of Management Studies, 36,* 3 (1999), 379–398.

12. Drucker, P. *Post-Capitalist Society.* New York: HarperCollins, 1993.

13. Earl, M.J., and Scott, I.A. What is a chief knowledge officer? *Sloan Management Review, 40,* 2 (Winter 1999), 28–38.

14. Fiol, C.M. Consensus, diversity, and learning in organizations. *Organization Science, 5,* 3 (1994), 403–420.

15. Gerbing, D.W., and Anderson, J.C. Monte Carlo evaluations of goodness of fit indices for structural equation models. *Sociological Methods and Research, 21,* 2 (1992), 132–160.

16. Grant, R.M. Prospering in dynamically-competitive environments: organizational capability as knowledge integration. *Organization Science, 7,* 4 (1996), 375–387.

17. Grant, R.M. Toward a knowledge-based theory of the firm. *Strategic Management Journal, 17* (Winter 1996), 109–122.

18. Hansen, M.; Nohria, N.; and Tierney, T. What's your strategy for managing knowledge? *Harvard Business Review, 77,* 2 (March–April 1999), 106–119.

19. Hartwig, F., and Dearing, B.E. *Exploratory Data Analysis.* Thousand Oaks: Sage Publications, 1979.

20. Hedlund, G. A model of knowledge management and the N-form corporation. *Strategic Management Journal, 15* (Summer 1994), 73–90.

21. Holtshouse, D. Knowledge research issues. *California Management Review, 40,* 3 (1998), 277–280.

22. Kim, L. Crisis construction and organizational learning: capability building in catching-up at Hyundai Motor. *Organization Science, 9,* 4 (1998), 506–521.

23. Kogut, B., and Zander, U. Knowledge of the firm, combinative capabilities and the replication of technology. *Organization Science, 3,* 3 (1992), 383–397.

24. Kusonaki, K.; Nonaka, I.; and Nagata, A. Organizational capabilities in product development of Japanese firms: a conceptual framework and empirical findings. *Organization Science, 9,* 6 (1998), 699–718.

25. Lawrence, P.R., and Lorsch, J.W. *Organization and Environment: Managing Differentiation and Integration.* Cambridge: Harvard University Press, 1967.

26. Liebeskind, J.P.; Oliver A.L.; Zucker, L.; and Brewer, M. Social networks, learning, and flexibility: sourcing scientific knowledge in new biotechnology firms. *Organization Science, 7,* 4 (July–August 1996), 428–443.

27. Magalhães, K. Organizational knowledge and learning. In G. von Krogh, J. Roos, and D. Kleine (eds.), *Knowing in Firms: Understanding, Managing and Measuring Knowledge.* Thousand Oaks: Sage Publications, 1998, pp. 87–122.

28. Maturana, H., and Varela, F. *The Tree of Knowledge.* Boston: New Science Library, 1987.

29. Nahapiet, J., and Ghoshal, S. Social capital, intellectual capital, and the organizational advantage. *Academy of Management Review, 23,* 2 (1998), 242–266.

30. Nelson, R., and Winter, S. *An Evolutionary Theory of Economic Change.* Cambridge, MA: Belknap, 1982.

31. Nonaka, I. A dynamic theory of organizational knowledge creation. *Organization Science, 5,* 1 (1994), 14–37.

32. Nonaka, I., and Konno, N. The concept of "ba": building a foundation for knowledge creation. *California Management Review, 40,* 3 (1998), 40–54.

33. Nonaka, I., and Takeuchi, H. *The Knowledge-Creating Company.* New York: Oxford University Press, 1995.

34. Nurmi, R. Knowledge intensive firms. *Business Horizons* (May–June 1998), 26–32.

35. O'dell, C., and Grayson, C.J. *If Only We Knew What We Know.* New York: The Free Press, 1998.

36. Pisano, G.P. Knowledge, integration, and the locus of learning: an empirical analysis of process development. *Strategic Management Journal, 15* (Winter 1994), 85–100.

37. Polanyi, M. *The Tacit Dimension.* London: Routledge and Kegan Paul, 1966.

38. Prahalad, C.K., and Hamel, G. The core competence of the corporation. *Harvard Business Review, 68,* 3 (May/June 1990), 79–91.

39. Raelin, J. A model of work-based learning. *Organization Science, 8,* 6 (1997), 563–578.

40. Schultz, U. Investigating the contradictions in knowledge management. In T.J. Larsen, L. Levine, and J.I. De Gross (eds.), *Information Systems: Current Issues and Future Changes.* Laxenberg, Austria: IFIP, 1999, pp. 155–174.

41. Singley, M., and Anderson, J. *The Transfer of Cognitive Skill.* Cambridge: Harvard University Press, 1989.

42. Snell, S.A., and Dean, J.W. Strategic compensation for integrated manufacturing: the moderating effects of jobs and organizational inertia. *Academy of Management Journal, 37,* 5 (1994), 1109–1140.

43. Spender, J.C. Making knowledge the basis of a dynamic theory of the firm. *Strategic Management Journal, 17* (Winter 1996), 45–63.

44. Stone, E.F., and Hollenbeck, J.R. Clarifying some controversial issues surrounding statistical procedures for detecting moderator variables: empirical evidence and related matters. *Journal of Applied Psychology, 74,* 1 (1989), 3–10.

45. Szulanski, G. Exploring internal stickiness: impediments to the transfer of best practice within the firm. *Strategic Management Journal, 17* (Winter 1996), 27–43.

46. Tsoukas, H. The firm as a distributed knowledge system: a constructionist approach. *Strategic Management Journal, 17* (Winter 1996), 11–25.

47. Van de Ven, A., and Delbecq, A. The effectiveness of nominal, delphi, and interacting group decision-making processes. *Academy of Management Journal, 17,* 4 (1974), 605–621.

48. Venzin, M.; von Krogh, G.; and Roos, J. Future research into knowledge management. In G. von Krogh, J. Roos, and D. Kleine (eds.), *Knowing in Firms: Understanding, Managing and Measuring Knowledge.* Thousand Oaks: Sage Publications, 1998, pp. 26–66.

49. von Hippel, E. "Sticky information" and the locus of problem solving: implications for innovation. *Management Science, 40,* 4 (1994), 429–439.

50. von Krogh, G., and Roos, J. A perspective on knowledge, competence and strategy. *Personnel Review, 24,* 3 (1995), 56–76.

51. von Krogh, G.; Roos, J.; and Slocum, K. An essay on corporate epistemology. *Strategic Management Journal, 15* (Summer 1994), 53–71.

52. Walsh, J.P. Managerial and organizational cognition: notes from a trip down memory lane. *Organization Science, 6,* 3 (1995), 280–321.

53. Weick, K.E., and Roberts, K. Collective mind in organizations: heedful interrelating on flight decks. *Administrative Science Quarterly, 38,* 3 (1993), 357–381.

54. Zack, M.H. Managing codified knowledge. *Sloan Management Review, 40,* 4 (1999), 45–58.

Appendix A: Confirmatory Factor Analysis for Knowledge Management Processes

Items[a]	Lambdas[b]
Scale 1: Externalization	
Modeling based on analogies and metaphors	0.63
Capture and transfer of experts' knowledge	0.62
Decision support systems	0.67
A problem-solving system based on a technology like case-based reasoning	0.73
Pointers to expertise (skills "yellow pages")	0.67
Chat groups/Web-based discussion groups	0.62
Groupware and other team collaboration tools	0.71
Scale 2: Combination	
Repositories of information, best practices, and lessons learned	0.53
Web pages (Intranet and Internet)	0.82
Databases	0.81
Web-based access to data	0.86
Scale 3: Socialization	
The use of apprentices and mentors to transfer knowledge	0.68
Brainstorming retreats or camps	0.53
Employee rotation across areas	0.49
Cooperative projects across directorates	0.72
Scale 4: Internalization	
Learning by doing	0.46
On-the-job training	0.53
Learning by observation	0.43
Face-to-face meetings	0.64

(continued)

Model	χ^2	d.f.	
Unconstrained model	127.79	129	χ^2/d.f. = 0.99; p-value = 0.51; GFI = 0.92; AGFI = 0.88; RMSR = 0.056; NFI[c] = 0.92

Baseline models			**Comparison with the unconstrained model**	
			χ^2 difference (χ_d^2)[d]	**Difference in d.f.**
1. Combined scales 1 and 2	211.25	132	83.46***	3
2. Combined scales 1 and 3	182.41	132	54.62***	3
3. Combined scales 1 and 4	199.22	132	71.43***	3
4. Combined scales 2 and 3	151.70	132	23.91***	3
5. Combined scales 2 and 4	162.56	132	34.77***	3
6. Combined scales 3 and 4	157.29	132	29.50***	3
7. Combined scales 1, 2, 3, 4	285.10	135	157.31***	6

[a] These items were measured by asking the following question: "Please indicate how frequently each of the following knowledge management processes and tools are used to manage knowledge at KSC by CIRCLING the appropriate number from 1 to 5" before the set of items. The item wordings are given above. The scales were anchored with 1 = Very Infrequently, 3 = Moderate Frequency, and 5 = Very Frequently.

[b] The lambdas are from the standardized solution. All t-values exceed 9.55 and are significant at $p \leq 0.001$.

[c] Based on null model with $\chi^2 = 1625.22$ and 190 degrees of freedom.

[d] Significance level: *** $p \leq 0.001$.

Appendix B: The Measures of Knowledge Effectiveness

Factor analysis (principal components method with Varimax rotation and Kaiser Normalization; eigenvalue greater than 1) of the 11 items used to measure knowledge effectiveness produced two clean factors only after five of the 11 items were dropped. Moreover, an examination of the scree plot indicated one factor. Factors 1, 2, and 3 had eigenvalues of 3.34, 1.05, with the corresponding variances explained being 0.64, 55.58, 17.34, and 10.39 percent. We therefore used the single factor, including the 11 items given below, to measure perceived knowledge effectiveness.

We would like to access your satisfaction with the knowledge available to you, to your directorate in general, and to KSC at an overall level. Please indicate the extent to which you disagree or agree with each of the following statement by CIRCLING the appropriate number from 1 to 5.

	Strongly Disagree		Neutral		Strongly Agree
1. You are satisfied with the availability of knowledge for your tasks.	1	2	3	4	5
2. The available knowledge improves your effectiveness in performing your tasks.	1	2	3	4	5
3. You are satisfied with the management of knowledge you need.	1	2	3	4	5
4. You are satisfied with the knowledge available for the tasks in your directorate.	1	2	3	4	5
5. You are satisfied with knowledge sharing among individuals at your directorate.	1	2	3	4	5
6. The available knowledge improves the effectiveness of your directorate.	1	2	3	4	5
7. You are satisfied with the management of knowledge at your directorate.	1	2	3	4	5
8. You are satisfied with the knowledge available for various tasks across KSC.	1	2	3	4	5
9. You are satisfied with knowledge sharing among various directorates at KSC.	1	2	3	4	5
10. The available knowledge improves KSC's overall effectiveness.	1	2	3	4	5
11. You are satisfied with the management of knowledge at KSC.	1	2	3	4	5