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An empirical model of the organization knowledge system in new product development firms

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Abstract

A structural equation model of the knowledge system for new product development (NPD) is derived from a sample of 1200 engineers in 10 technology firms, and validated on a hold-out sample. Core to the model are knowledge work behaviors that: (1) expand knowledge relevant to NPD by focusing on the performance of the organization as a system; (2) increase knowledge available by linking knowledge sources with needs; (3) access procedural knowledge by using systematic processes; and (4) generate knowledge by trying new approaches and experimenting. We examine the organizational antecedents of these behaviors, and their impacts on knowledge outcomes and organizational effectiveness.

Keywords: New product development; Knowledge management

1. Purpose and background

This study proposes a model of the knowledge system in the new product development (NPD) firm and tests it in ten large technology firms. The purpose is to define the various aspects of the organization that contribute to the firm's ability to generate advantage based on "knowledge and knowing capabilities", or intellectual capital (Nahapiet and Ghoshal, 1998, p. 245). We build on the works of Dougherty (2001) and others that view the NPD organization as a sensemaking system and the work of developing products as sensemaking. Our primary focus is on knowledge work behaviors, the organizational features that foster

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them, and how these behaviors contribute to the creation and application of knowledge for organizational effectiveness.

Because knowledge is increasingly important to competitive advantage (Seely-Brown and Duguid, 2000), firms are focusing on their knowledge generating competencies. New knowledge is required to create an ongoing stream of new products and methods, and to grow an organization's capabilities (Leonard-Barton, 1995; Nonaka and Takeuchi, 1995). Increasing the firm's proficiency at deriving competitive value from knowledge requires understanding what aspects of the organization's work system and organizational design affect its ability to acquire, create, and apply knowledge.

Much of the literature on managing knowledge in organizations has dealt with specific elements of the knowledge enterprise, such as organizational memory (Cross and Baird, 2000), knowledge transfer (Dixon, 2000; Szulanski, 1996), the design of technology tools for knowledge sharing (Davenport and Prusak, 1998); building the social networks that foster knowledge (Brown and Duguid, 1991; Wenger, 1998); and developing a knowledge strategy (Zack, 1999). There is increasing recognition, however, that the impacts of these elements depend on other features of the organizations in which they are used (Davenport et al., 1998). The ways that knowledge workers are organized and managed determine the success of knowledge enterprises in general (Quinn et al., 1996), and of NPD organizations in particular (Dougherty, 2001). Most literature examining these issues has been qualitative, much of it based on case studies, and it has yielded a rich picture of particular projects, programs, and approaches. Our intent is to quantitatively develop a model of the NPD organization as a knowledge system that results in new knowledge and its effective application. Such a model can provide information useful in integrating the various prongs of the literature on knowledge management and in designing organizations to foster NPD.

We examine NPD enterprises as experienced by the engineers and scientists who work in them and have to make sense of the system in which they are embedded and of the work they are doing. In the following sections, we build a conceptual model of this system. Then we explain our method, which is to use structural equation methodology and survey data to empirically refine our model with one sample of NPD knowledge workers, and test the refined model with a different sample. Our results are presented, followed by a discussion and some concluding remarks.

2. Conceptual model

The essence of the NPD firm is the creation of new knowledge and using it to solve problems and create products that have value in the marketplace. Knowledge is contextual and relational—people construct knowledge as they interact in a social context, and this knowledge in turn influences their behaviors, perceptions, and cognitions (Berger and Luckmann, 1966). Knowledge is "information combined with experience, context, interpretation and reflection" (Davenport et al., 1998). The process by which meaning is attached to a stream of experiences, information, insights, and ideas has been labeled "sensemaking" (Weick, 1995). Scientists and engineers engaging in NPD bring to their work the formal and articulated expertise of their disciplines that have been socially constructed through time by particular professional or academic communities. This knowledge

initially frames their attention when they approach a problem; however, by making sense of particular problems and of the information they encounter in particular situations, and by taking action and revising their interpretations, they develop new knowledge, both tacit and explicit.

Weick (1995) identified two collective sensemaking approaches that operate simultaneously and in interaction with one another. Person-to-person, or "intersubjective" sensemaking is necessary to share interpretations and explore possible meanings in order to make sense of situations where formal knowledge frameworks are insufficient and/or where tacit knowledge is being applied. Several engineers, for example, may examine surprising test results and share their different disciplinary perspectives and experience-based tacit understandings about why these results occurred. This form of collective sensemaking, entailing personal links between people with different knowledge, can yield new knowledge. Knowledge can be linked across the organization if it can be accessed through interactions, or transactions (Wegner, 1986).

"Generically subjective" sensemaking is the second form of collective sensemaking described by Weick. It entails making sense of knowledge that has been formally articulated and made available in the form of shared understandings. These shared understandings may be embedded in procedural form in systematic work processes, tools, and algorithms; or articulated as strategies, goals, roles, structures, technology roadmaps, and system architectures (Dougherty et al., 2000, p. 324). This form of knowledge may have been the result of past intersubjective sensemaking, but now exists as shared frameworks and resources. This knowledge may be accessed by following the systematic procedures in which it is embedded, or through accessing archivally available knowledge, such as best practice descriptions, "lessons learned" documents, and statements of organizational strategy.

Because knowledge is both applied and generated in the course of doing work, the effectiveness of the NPD enterprise depends on the richness of the knowledge that employees bring to bear in solving problems and the likelihood that they try new approaches and generate new interpretations. Stimulating knowledge acquisition, application, leverage, and creation in the NPD enterprise requires far more than making information available to people (Dixon, 2000). Information yields knowledge when it becomes "anchored in the beliefs and commitments of its holder" (Nonaka and Takeuchi, 1995) through active involvement in its creation, and/or through collective sensemaking and local learning as it is applied (Orlikowski and Robey, 1991). A challenge for the NPD firm is to design and create an organizational context for the work that makes it more likely that employees will attend to different information, attach new meanings, and try new approaches as they make sense of their technical problems.

Fig. 1 presents a conceptual model of the NPD organization as a knowledge enterprise—one whose success in the marketplace depends on its effectiveness in creating knowledge and applying it in products and services that deliver value to the customer and yield a financial return to the firm. It consists of four high-level constructs that together form the knowledge system: (1) contextual organizational elements; (2) knowledge work behaviors; (3) knowledge outcomes; and (4) effectiveness. Below we present the conceptual basis for each of the general constructs, the variables we choose to more specifically define the construct, and the relationships we expect with the other constructs and their variables.

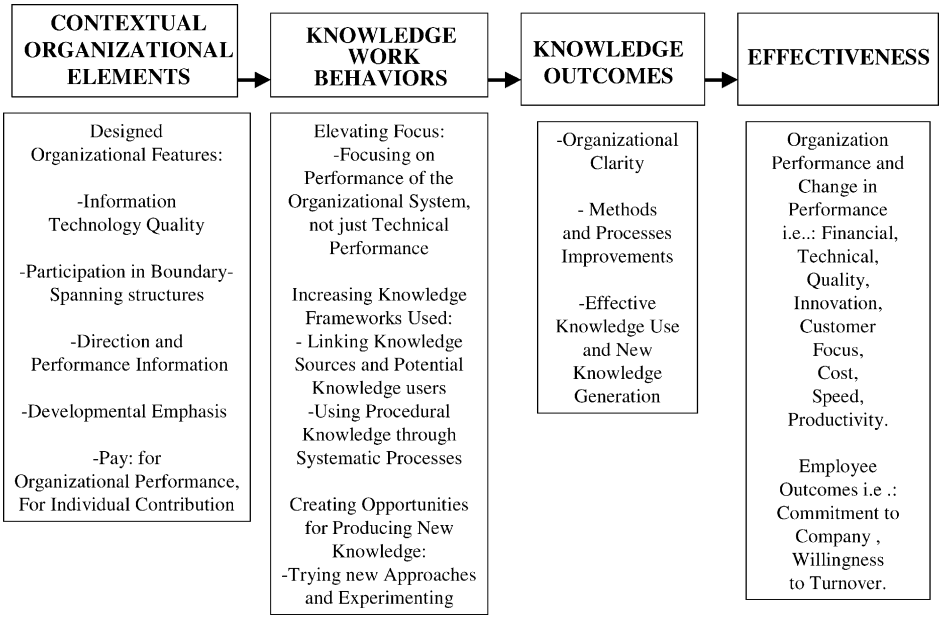


Fig. 1. Conceptual model of NPD organization knowledge system.

2.1. Contextual organizational elements

The first column refers to features designed into the organization that houses the new product development work. An organization's design is its configuration of technologies, structures, practices and processes (Huber and Glick, 1993) that can purposefully support organizational strategies and capabilities. The organization's design is important because it shapes behavior through: the distribution of resources, authority, and information; the nature of the formal connections, groupings, and roles in the organization; and the tools provided to do the work (Galbraith, 1994). Scholars have pointed out the impact of contextual elements on knowledge management, mentioning such features as structures, socialization and development processes, communication mechanisms, social networks, rewards, and technology tools (e.g. Anand et al., 1998; Finegold et al., 2002; Griffith, 1999; Quinn et al., 1996). We expect the following elements of the organization to be especially important in shaping the knowledge work behaviors of the organization. These are the elements that enable and motivate employees to reach beyond the knowledge they carry in their heads as they go about solving technical problems.

2.1.1. Information technology (IT) quality

The knowledge management literature has focused on IT tools and their potential to support collaboration among people with different knowledge bases (e.g. Boland and Tenkasi, 1995); to enable knowledge access and sharing including connections to company experts (Anand et al., 1998); and to disseminate generic and codified knowledge, including algorithms and systematic work processes that embody the knowledge of the firm (Cross and

Baird, 2000; Fulk and DeSanctis, 1999; Leonard-Barton, 1995). Defined in terms of these potentialities, high quality IT is expected to foster working in a way that takes an expanded focus and draws in more knowledge.

Although many knowledge management programs started out as IT solutions, the management literature increasingly views IT as but one element of knowledge management: useful for storage and distribution of explicit knowledge, but less helpful for sharing tacit knowledge and stimulating the use or creation of knowledge (Anand et al., 1998; Davenport and Prusak, 1998).

2.1.2. Participation in boundary spanning structures

The NPD literature has emphasized the importance of structures that span boundaries and bring together contributors with a range of knowledge and perspectives (e.g. Brown and Eisenhardt, 1995; Clark and Fujimoto, 1991; Jelinek and Schoonhoven, 1990; Mohrman et al., 1995). Collaboration and multidisciplinary problem-solving are increasingly required in today's NPD world as many of the most important problems and consequently much knowledge creation occurs at the intersection of disciplines and functions (Boland and Tenkasi, 1995; Iansiti, 1995; Leonard-Barton, 1995). Formal boundary spanning structures such as cross-functional teams are forums where intersubjective sensemaking (Weick, 1995) may occur to address novel problems that require combining knowledge to generate solutions.

Indeed, participation in boundary spanning structures such as cross-functional teams and product councils has been found to lead to expanded innovative sensemaking (Dougherty et al., 2000; Iansiti, 1998), because it exposes employees to knowledge from different disciplines and functions in the course of addressing complex technical, market, and business NPD challenges. When people are embedded in a network of cross-boundary work relationships it can expand their focus of attention and link them to the organizational memory (Anand et al., 1998; Cross and Baird, 2000).

2.1.3. Direction and performance information

New products are developed in the context of the strategies that have been set and translated into business plans, goals, and activities for the company and its various units and projects (Dougherty, 2001). Goals, metrics, plans, and milestones are among the generically subjective sensemaking frameworks of the organization and are intended to create shared understanding about standards and targets (Weick, 1995). They focus employees' attention, and motivate higher levels of performance (Locke and Latham, 1990). They can make employees aware of the areas and levels of performance required for market success and may lead to seeking out knowledge and trying new approaches that allow product and process breakthroughs and continual improvement. Performance information and feedback is a necessary companion to goals so that knowledge workers know the degree to which goals are being attained. Organizational practices that communicate performance direction and performance information can affect whether employees are aware of what the NPD enterprise is achieving and trying to achieve so they can take this knowledge into account as they do their work. Information about goals and performance may also make evident areas requiring technical breakthroughs because current understanding is inadequate, and thus trigger sensemaking activities including the trying of new approaches (Louis and Sutton, 1991).

2.1.4. Developmental emphasis

Human resource practices are important contextual elements that impact employee behavior. For example, through formal training and development and through carefully planned job and team assignments and rotations, companies expose employees to many perspectives and expand their focus, the knowledge they can apply to solve problems, and the social network they can draw on to access and share knowledge (Adler and Kwon, 2002; Hansen, 1999). Development of employees should also increase the ability to import knowledge. Capacity to absorb new knowledge has been found to depend on the existing stock of knowledge that makes it possible to notice and place value on new knowledge, assimilate it, and apply it (Cohen and Levinthal, 1990; Huber, 1991; Szulanski, 1996).

Developmental emphasis reflects the priorities of the organization and its managers. When organizations emphasize development, we should expect expansion of employees' focus and their ability both to apply knowledge that is embedded in systematic processes and to link to new knowledge held across the organization.

2.1.5. Pay

Aligning rewards with the knowledge strategies and goals of the organization has been frequently mentioned as key to successfully managing knowledge (Davenport et al., 1998; Quinn et al., 1996). Rewards can motivate and focus employee attention on particular kinds of performance (Lawler, 1990). Rewarding for individual performance focuses employees on their own performance and rewarding for broader organizational performance focuses them on how to contribute to their team and/or to the overall unit or company performance. Pay based on broader organizational performance is expected to motivate the collective sensemaking through which complementary knowledge is brought to bear on complex problems, and the importing and sharing of knowledge across the organization. Pay for individual performance, on the other hand, is expected to focus the employee more narrowly on individual performance and perhaps to discourage collective knowledge work behavior (Mohrman et al., 1990). Paying for individual competencies can focus the employee on developing skills and knowledge required for effective performance and thus can foster an increase in the amount of knowledge the employee can bring to bear on the problem.

2.2. Knowledge work behaviors

In the second column, we categorize four work behaviors by the three ways they can broaden knowledge used during NPD: (1) elevating focus by attending to more aspects of the situation from a more systemic perspective; (2) increasing the number of knowledge bases that are brought to bear on problems; and (3) creating opportunities to generate new knowledge by taking action and learning from it.

2.2.1. Elevating focus

In studying high reliability organizations, Weick and Roberts (1993) described complex, often tacit ways of interrelating so that people in each part of the organization take into account (are heedful of) the related work going on in other parts of the system. Dougherty et al. (2000) describe a similar dynamic in NPD firms, requiring organizational sensemaking

that transcends purely technical work. NPD work occurs in an organizational setting characterized by a relentless pace of projects required for competitiveness and market leadership, requirements for linking technology to multiple, diverse market opportunities and customer applications, and pressure to receive sufficient financial return to enable ongoing investment in knowledge and new product generation. Although the problems of strategy, customer satisfaction, competitiveness, and financial viability may be addressed through activities going on in different parts of the organization, the work in each of these domains impacts the work in the others, and some level of shared understanding and integration is required. For example, how the technical NPD work is carried out affects the resource requirements and cost of product development. Thus, new product developers need to be heedful of the firm's requirements for speed, cost, customer satisfaction, and other aspects of performance that determine whether the firm can achieve its business goals and carry out its strategy effectively. *Focusing on system performance* of the broader organization and business requires developers to elevate their focus to a higher systemic level and thus attend to a broader set of information and consider more inclusive perspectives.

Iansiti (1998) and Leonard-Barton (1995) are among the scholars who have found that defining problems broadly contributes to breadth of input, efficiency of integration, and innovativeness in technical work. Dougherty et al. (2000) found that the sensemaking activities in more innovative NPD firms weave in attention to business and strategic information from different levels in the organization.

2.2.2. Increasing the knowledge frameworks used

Extending the knowledge that is brought to bear on a problem requires mechanisms for accessing knowledge that is held elsewhere (Anand et al., 1998).

Linking knowledge across the organization is a core concept of the knowledge management literature. Sharing and accessing knowledge across the organization extends the knowledge available to product developers that can be applied to the problems they seek to solve. This sharing may occur in a number of ways, such as electronically, by drawing on personal network contacts or calling on company experts, and/or through task-oriented exchange in the course of participating in teams and groups.

An especially important source of generically subjective knowledge is in the form of the work processes used in NPD work. Knowledge can be captured about earlier sensemaking endeavors and used to create systematic procedural platforms that guide decision-making and work. Through the use of these systematic organizational processes, process and content knowledge is leveraged and organizational memory is facilitated, bringing previously learned knowledge to bear on new problems. *Using systematic processes* also provides a platform for ongoing process improvements as new approaches are tried and new procedural knowledge is incorporated into the processes (Cross and Baird, 2000; Leonard-Barton, 1995).

2.2.3. Creating opportunities for producing new knowledge

New knowledge can be created by *trying new approaches* in the effort to make sense of a particular problem situation, and by learning from what happens (Weick, 1995; Huber, 1991). This sensemaking activity may be triggered because a situation is novel and does not fit known approaches; because known approaches fail, yielding a discrepancy that has

to be resolved; or because experimentation is intentionally carried out to find a better approach (Louis and Sutton, 1991; Griffith, 1999). Trying new approaches is fundamental to learning and innovation. This behavior extends knowledge through experiential learning. The important aspect of this behavior is the degree to which it is a norm in the NPD setting.

2.3. Knowledge outcomes

The knowledge work behaviors in the second column focus on the various ways knowledge workers can broaden the spectrum of knowledge accessed during the NPD sensemaking processes. In the third column are various forms of knowledge, including applied knowledge, that are the socially constructed outcomes of sensemaking. These knowledge outcomes are expected to lead to higher levels of effectiveness in general. The pertinent domains of knowledge outcomes include not just those inherent in the new products, but also in the methods and processes to be used in development and production, as well as knowledge about the market, about the organization, and the strategic direction of the business (Dougherty et al., 2000).

2.3.1. Organizational clarity

By this we mean the clarity with which NPD participants understand their organization. Clarity of the meanings attached to the organization, including its strategies, priorities, and operating logic, is created in the course of the exchanges and experiences that occur while carrying out the NPD activities of the firm. This is not the same as the organization information that people access in the course of doing their work. Rather, it is the socially constructed knowledge about the organization that *results from* the sensemaking inherent in NPD. Such sensemaking broadens awareness and provides experiential understanding and clarification of the organization and its purpose, and of the meaning of one's work in the context of the organization.

2.3.2. Methods and processes improvement

Processes and methods are part of the generically subjective sense of the organization (Weick, 1995)—shared frameworks that embody sense that has been previously made and that provide meaning to and guide activity across the organization. In their concrete form they can include such things as work processes of an organization, the ways projects are organized and managed, and decision-making algorithms. They embody knowledge and capabilities for knowing, and as such are an important part of the intellectual capital of the firm (Nahapiet and Ghoshal, 1998). Improved methods and processes have been redesigned to incorporate new knowledge.

2.3.3. Effective knowledge generation and use

This outcome represents the duality of sensemaking: existing knowledge is used to address novel problems, and the interpretations of the effectiveness of the actions taken can result in new knowledge (Weick, 1995) that becomes part of the knowledge base available to be applied to subsequent problems. Thus, knowledge use and generation of knowledge are social constructions that result from the same sensemaking activities that constitute the

NPD work. An important outcome for the knowledge system is how effectively knowledge is generated and used.

2.4. Effectiveness: organizational performance outcomes

2.4.1. Overall performance

Competitiveness in today's global knowledge economy demands that the firm have organizational competencies along multiple dimensions (Galbraith and Lawler, 1998), including cost, quality, productivity, customer focus, speed, innovation, technical excellence and financial performance. Overall performance is a composite of the company's effectiveness on these various dimensions for which the standards transcend the metrics for a particular project or unit (Dougherty, 2001).

2.4.2. Change in performance

By change in performance we mean the amount of recent improvement (or decline) in these same dimensions. Recent change in performance should contribute to overall performance.

2.5. Effectiveness: employee outcomes

Because the knowledge system depends on retaining a competent and committed workforce as part of the value created, we also consider employee outcomes, such as their commitment to the organization and their willingness to leave for other opportunities, to be an aspect of the NPD organization's effectiveness.

2.5.1. Commitment to company

Commitment to company is the strength of an individual's identification with and attachment to the organization, including belief in its goals and willingness to exert effort on its behalf (Porter et al., 1974). In some studies, commitment has been found to be positively linked to work performance (e.g. O'Reilly and Chatman, 1986; Randall, 1990) and negatively related to turnover (e.g. Huselid and Day, 1991; Somers, 1995). Commitment is a particularly important outcome in an NPD knowledge system, where employees need to actively apply their competencies to increase organizational knowledge and create value. Recognizing the importance of this affective variable, Ulrich (1998) defines a firm's intellectual capital as comprised of the competency and commitment of knowledge workers.

2.5.2. Willingness to turnover

Willingness to turnover has been found to relate to searching for other job opportunities (Mobley et al., 1978). When experienced technologists walk out the door, their knowledge, particularly experience-based, tacit aspects, is no longer available to the organization. Turnover may reduce the intellectual capital of the firm and detract from efforts to develop and grow its competencies. Since commitment has been shown to negatively relate to turnover, we expect it to have the same relation to willingness to turnover.

The next section describes the study methods, including the sample and data collection procedures, the measures and the analytic approach.

3. Methods

While Fig. 1 is a model of the organization knowledge system, we choose to examine it as it is understood by the individuals who must make sense of their organizational settings. To this end, we operationalize and measure individuals' understandings of the model's variables in their work situations. First we use SEM to test the initial sequential model in Fig. 1 and through iterations derive a more refined and systemic one that reveals the impacts of its various components throughout the system. Finally, we validate this refined model using a hold-out sample. The sample and data collection procedures are described next.

3.1. Sample and data collection procedures

In order to develop a robust model of the NPD knowledge system, we drew our sample from ten NPD firms developing a variety of complex systems such as aircraft engines; software systems that monitor, integrate, and interpret data; chemical processing technology; agricultural machinery; vehicles; and weapons systems. A typical program entails the development of new components, applications, and system architectures. All of the firms were characterized by numerous simultaneous new product development projects, and all competed in their industries on the basis of multiple technological, scientific, and design breakthroughs. The companies are large, well-established organizations developing new process and product technologies. Sampling and survey administration procedures varied depending on the size and physical dispersion of the technical workforce. Anonymous surveys were administered to either all or a random sample of the scientists and engineers engaged in NPD. The surveys were either group administered or distributed through the internal mail system with a pre-paid envelope and returned directly to the researchers. In all, 3596 of the 6766 distributed surveys were returned. This overall response rate of 53% ranged from 35 to 69% across the companies.

The average age of the respondents is 42.7 years. Females make up 14% of the sample. Six percent of the sample have doctorates as their highest level of educational achievement, 27% master degrees, 39% bachelor degrees, and 14% have bachelor degrees along with some graduate work. Fourteen percent of the sample had associate degrees in engineering and/or had attained on-the-job equivalency. Average tenure with the company is 13.7 years and in their current position 42.2 months. Team leaders are 17.5% of the sample, managers 17.7%, with the remainder being individual contributors.

3.2. Measurement

The data were collected using a survey instrument designed to measure the elements, behaviors and outcomes in the model. The unit of analysis for testing the model is the individual, and all measures reflect the knowledge worker's perceptions of and experiences in the system. This approach reflects the core role of the knowledge worker in a system that depends on the application and generation of socially constructed knowledge, and the importance of the meaning that the individual attaches to the system.

Most of the survey measures were created expressly for this study, as these issues have in the past largely been investigated using qualitative methodology. In order to build and validate our measures, we first split our sample in half randomly. After verifying that the demographics of the two samples were equivalent, we set aside one half as a "hold-out sample" for testing the reliability of our final measures on a sample not used to build them. On the remaining "working" sample, we went through the following steps: (1) a priori groupings of items developed to measure each construct were initially explored using traditional factor analysis techniques. Some items not loading strongly on the variables as hypothesized were discarded. (2) Final scales were validated with confirmatory factor analysis using structural equation modeling (SEM) using the Amos 4.0 package (Arbuckle and Wothke, 1999). (3) Items in each final group were averaged to form a scale representing that variable. Cronbach alpha reliabilities were calculated for each scale where appropriate (see Appendix A for items, scales and Cronbach alphas.). Each scale is described below.

3.2.1. Contextual organizational elements

Each of the context variables is measured in terms of how it impacts the respondent, not in terms of the absolute character of the feature's design in the organization.

Information technology quality measures respondents' perceptions of the quality of their computer and information systems as tools in support of their new product development work.

Participation in boundary spanning structures counts how many of four different kinds of lateral structures the respondent actively participates in: cross-functional project teams; problem-solving and improvement teams; councils or committees; and knowledge-sharing networks. Respondents were given a score from 0 to 4 based on self-reported membership in these structures. Although a measure of internal consistency does not make sense for this variable, confirmatory factor analysis showed all four to be significant indicators of the same latent variable.

Direction and performance information asks how well informed the respondent feels about various types of company, project and business unit goals, plans and performance progress.

Developmental emphasis measures how much emphasis there is on training and development, if there is a good mentoring process, and whether job assignments allow employees to develop new skills and knowledge.

Pay for organizational performance measures whether respondents feel they are rewarded based on how well the firm performs.

Pay for individual contribution measures whether respondents agree that their pay is based on individual performance, skills, and contribution.

3.2.2. Knowledge work behaviors

These variables are measured as the respondents' perceptions of behavioral practices or norms. These may or may not imply formalization of the practices.

Focusing on system performance measures whether the respondent perceives that employees elevate their focus beyond narrow technical issues by regularly considering the impact of their technical work on quality, cost, and overall business objectives and performance.

Using systematic processes measures the application of procedural knowledge through the use of established and orderly approaches for conducting projects, solving problems, making decisions and trade-offs, and learning from project results.

Knowledge linking measures ease of access to and regular sharing of lessons learned, solutions to problems, and useful information.

Trying new approaches measures whether offering new ideas, trying out new approaches, and risk-taking are encouraged and practiced.

3.2.3. Knowledge outcomes

These variables are measured by items that express accomplishment and quality, not the behaviors that may have led to them.

Effective knowledge generation and use is a self-report of how effective the respondent's unit has been at generating new knowledge and incorporating knowledge from elsewhere into its work.

Methods and processes improvements is a self-report of the extent to which the respondent's unit has made improvements in its work methods and processes.

Organizational clarity measures whether the respondent perceives that the organization—its structure and logic, strategy and goals—is well defined, aligned, and clearly understood.

3.2.4. Effectiveness: employee outcomes

These are measures of the respondent's current affect and state of mind.

Commitment to company measures the respondent's affective attachment to the organization.

Willingness to turnover assesses whether a respondent would be willing to change companies.

3.2.5. Effectiveness: organization performance

These variables are measured in terms of perceived levels of effectiveness and positive or negative progress.

Overall performance outcome variable is the respondents' self-rating of various dimensions of their unit's effectiveness at delivering on the value creation proposition. It includes the dimensions of cost, quality, productivity, customer focus, speed, innovation, technical and financial. Although the dimensions are quite generic, they were confirmed in preliminary interviews with top management in each company to be the outcomes essential to accomplishing the firm's value proposition.

Change in performance measures whether respondents feel their business has improved (or declined) on these same performance dimensions.

Attempts to subdivide both of these performance scales into types of performance failed statistically. The individual items of each resolutely stuck together, indicating strong underlying factors.

3.3. The initial model

Our starting hypothesis is that the system of causal paths embodied in the model of Fig. 1 will statistically fit with the data. This is a general model, in that we hypothesize

that all variables in each column will cause all variables in the immediate column to their right. It is a " naive" model, in that we do not pretend to conceptually sort out the relative size of the causal paths or predict which paths might disappear when controlling for the presence of the other variables. We also "naively" do not initially hypothesize any causal paths among variables in non-contiguous columns or within either of the two middle columns. The contextual organizational variables, however, are independent, and we assume that they will covary. Within the effectiveness column we, less naively, hypothesize that commitment will predict willingness to turnover and change in performance will predict performance.

3.4. Analyses

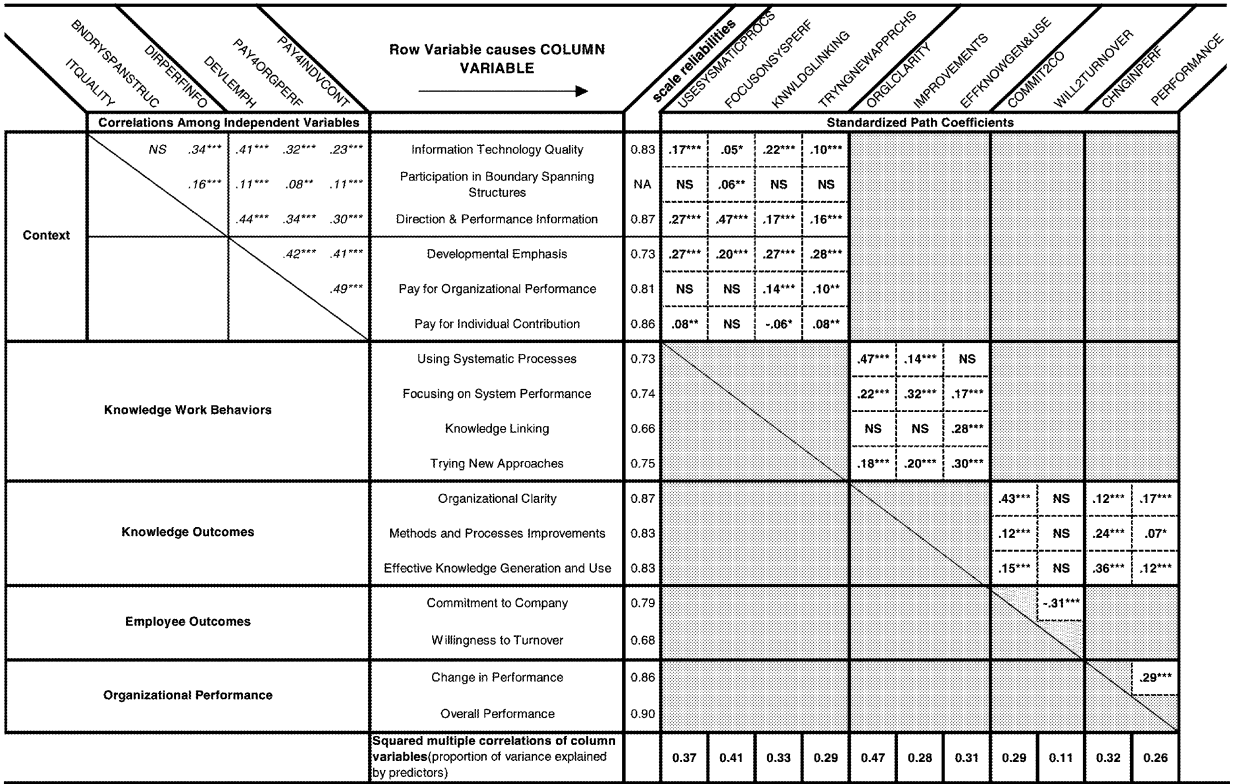
We use structural equation modeling (SEM) to test our model as a system (Arbuckle and Wothke, 1999). SEM is appropriate because it tests the degree to which our hypothesized system model fits with the data by simultaneously calculating the maximum likelihood estimates of the parameters of the model (Hayduk, 1987; Joreskog and Sorbom, 1989).

We use an iterative approach. We first run our initial model and subsequent derivations on the "working" half of the sample, saving the "hold-out" half for use in a final confirmatory step. We use the initial working sample results (significance of estimated path coefficients and modification indices for those paths originally set to zero) to derive an improved model of the knowledge system which we again test for fit with the data. We repeat this cycle of test, improve, test; iteratively adjusting our model to obtain increasingly better fit with our working sample (Arbuckle and Wothke, 1999). Finally, when we can no longer improve fit by subsequent adjustments, we retest this derived model on the hold-out sample to determine the model's reliability.

Although Table 1 is primarily a reporting of initial results, it is also a matrix representation of our initial hypothetical model. All paths in Table 1 are specified as single-headed arrows going from row variables to column variables. These are the paths that are hypothesized to exist and that are estimated. The paths not estimated are hypothesized to not exist and are set to zero. As is standard in regressions and path analyses, we assume the independent variables are likely to covary, and we estimate this covariance (standardized as correlations). Finally, each dependent variable is specified as being connected to an exogenous latent error variable by a path with a fixed coefficient of one. Each error term is specified as independent of all other terms in the model.

Given our large sample size, over 1200 in each half (after listwise deletions of missing data), we test the fit of our model using the four standard indices of fit that are least susceptible to sample size: the ratio of the discrepancy (used for the χ^2-test) and the degrees of freedom (d.f.) in the model, considered adequate when less than 5 or, more stringently, when 3 or less (Arbuckle and Wothke, 1999; Hayduk, 1987); the Tucker–Lewis index (TLI), and the comparative fit index (CFI) both of which indicate acceptable fit when greater than 0.90–0.95 (Bagozzi and Edwards, 1998; Vandenberg and Lance, 2000). Finally, we use the root mean square error of approximation (RMSEA) which indicates increasing fit by smaller values; 0.08 is considered an upper limit with less than 0.06 considered more appropriate (Landis et al., 2000; Vandenberg and Lance, 2000).

Table 1
Initial structural equation model of NPD organization knowledge system: results from and fit with working sample



4. Results

When the initial model is tested with the working sample, the fit is unacceptable but encouraging (Table 1). We therefore rejected our initial model, and used the modification indices to identify paths that we had not predicted but that were most likely in operation. We also identified initial but non-significant paths that could be set to zero. We then engaged in a sensemaking process about these initial results and further thinking about the theory and a more nuanced consideration of potential dynamics among the variables. We also investigated the possibility of non-recursive models in which there might have been mutual causation between some variables. Three iterations led to an "optimum fit" model for our working sample (Table 2) that we then tested as our derived hypothesis with the hold-out sample (Table 3). All fit indices with both samples indicate a very high degree of fit between the derived model and the data, as shown at the bottoms of the tables. For ease of interpretation, in all tables we have ordered the variables within the groupings so that any paths that we discovered among them (during iteration) fall above the diagonal.

Since our theory driving this research is relatively general and high level, as expressed in Fig. 1 and Table 1, the changes made for the derived model amount to fine-tuning and are still consistent with the thrust of the original model. The recursive, linear flow of causation across the model from left to right and the general placement of the context, knowledge system, knowledge outcomes, and effectiveness variables all remain inviolate. There were no modification indices that indicated there are any paths going from right to left in the model. The model's overarching logic, that the organization's knowledge management capabilities lead to higher levels of organizational effectiveness, is substantiated. In general, the paths between contiguous groups of variables in Fig. 1 are somewhat larger than the paths between more logically and causally distant groups of variables. In the hold-out sample, the derived model explains 32% of the variance of overall performance, 35% of change in performance, and 49% of commitment. The organizational context features and knowledge work behaviors together account for 56% of clarity, 38% of improvement, and 40% of effective knowledge generation and use. The organizational context features account for from 34 to 43% of the knowledge work behaviors. The derived model fits well with both samples. Only one path in Table 2 is not significant in Table 3.

Our choice of contextual features and knowledge work behaviors was guided by the theoretical perspective that new knowledge and new uses for knowledge are socially constructed through sensemaking processes, and that success in NPD depends on fueling sensemaking with a wide set of pertinent knowledge frameworks. The derived model is consistent with this perspective.

Below we report the significant paths in the final model. In Section 4.1, we discuss these results, focusing on understanding particular paths in the model that relate to the influence of contextual variables on knowledge behaviors and outcomes.

4.1. Organizational contextual elements

Direction and performance information has a pervasive impact on knowledge work behaviors, relating significantly to three of the four knowledge behaviors: focusing on system

Table 2
Derived structural equation model with best fit run on working sample

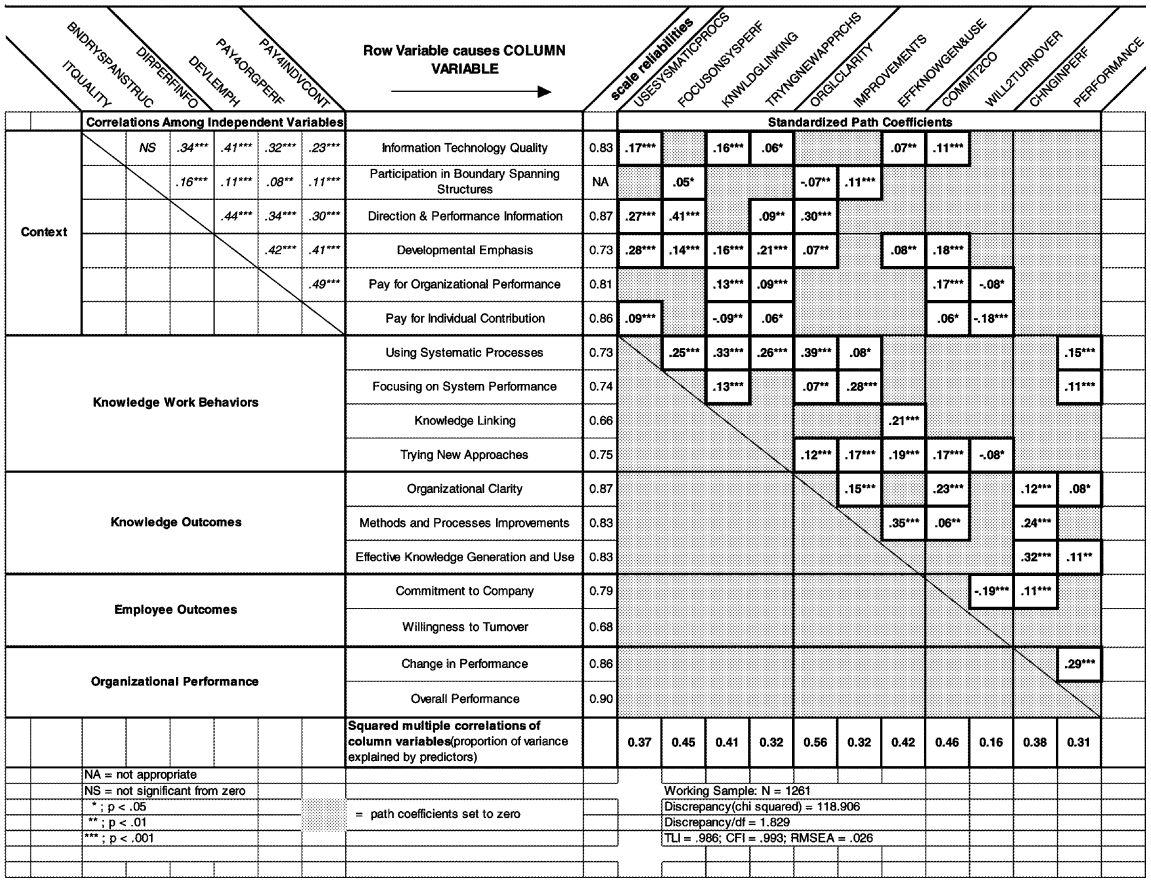
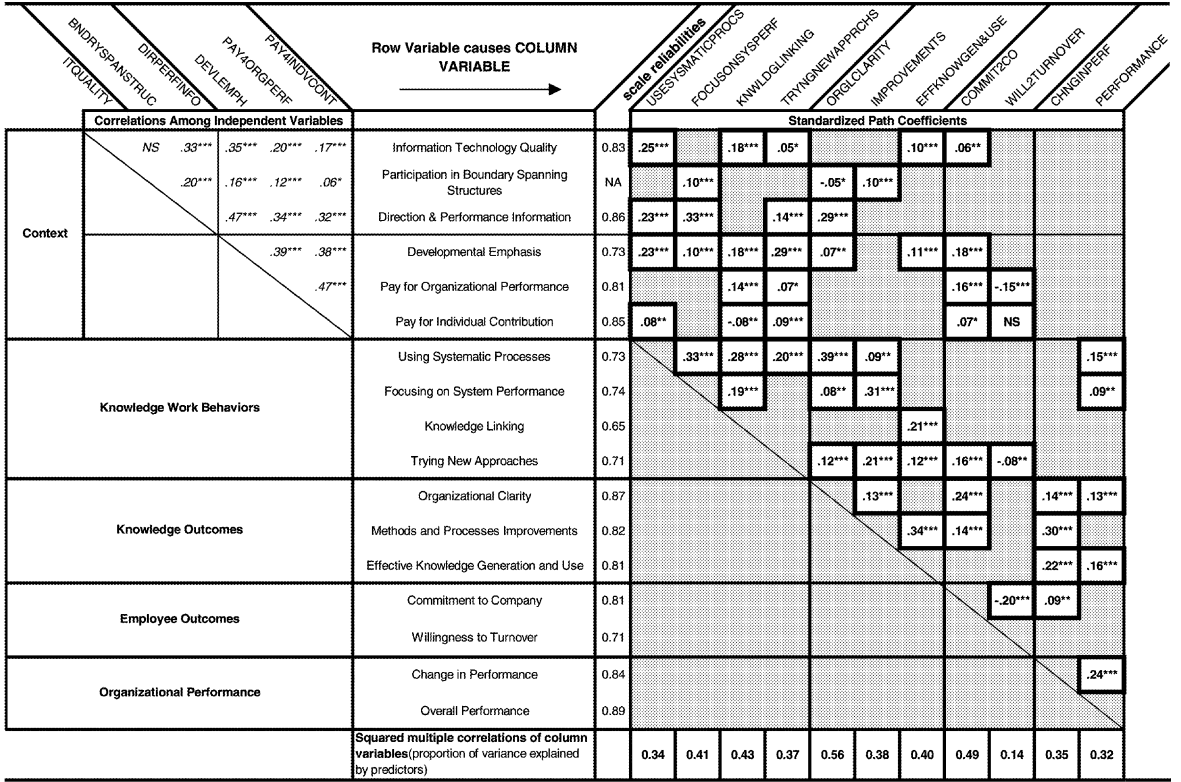


Table 3
Results of testing the *derived* structural equation model as hypothesis on the hold-out sample



performance, using systematic processes, and trying new approaches, but not to knowledge linking. It also relates directly to organizational clarity.

IT quality contributes to three knowledge work behaviors, using systematic processes, knowledge linking, and (weakly) to trying new approaches. It also relates directly, although weakly, to one knowledge outcome, effective knowledge generation and use, and, also weakly, to one effectiveness variable, commitment to company.

Participation in boundary spanning structures relates weakly to one knowledge work behavior, focusing on system performance. It relates directly, also weakly, to two knowledge outcomes: positively to methods and processes improvements and negatively to organizational clarity.

Of the human resource practices, developmental emphasis has a pervasive impact in the NPD organization. It has significant paths to all four knowledge work behaviors and to two knowledge outcomes: organizational clarity and effective knowledge generation and use. It is also positively related to commitment to company.

Pay for organizational performance relates to knowledge linking and weakly to trying new approaches, while pay for individual contribution relates weakly positively to using systematic processes and trying new approaches and negatively to knowledge linking. Both pay variables relate positively to commitment to company and pay for organizational performance relates negatively to willingness to turnover. The hypothesized path from pay for individual contribution to willingness to turnover is not significant in the hold-out sample.

4.2. Knowledge work behaviors

Only trying new approaches predicts all three knowledge outcomes. It also relates positively to commitment to company and negatively (weakly) to willingness to turnover. Focusing on system performance relates to methods and processes improvements and weakly to organizational clarity. It has a direct but weak link to overall performance. Using systematic processes weakly predicts methods and processes improvements and has an especially strong link to organizational clarity. It also has a direct path to overall performance. Knowledge linking relates only to effective knowledge generation and use.

There are also some interesting relationships among the knowledge work behaviors themselves. Both focusing on system performance and using systematic processes foster knowledge linking. Using systematic processes also leads to knowledge linking and trying new approaches.

4.3. Knowledge outcomes

All three knowledge outcomes relate to change in performance. Organizational clarity and effective knowledge generation and use also predict overall performance. Among the knowledge outcomes, organizational clarity explains methods and processes improvements which, in turn, explains effective knowledge generation and use. Organizational clarity and methods and processes improvements predict commitment to company, but no knowledge outcomes relate to willingness to turnover.

4.4. Effectiveness

Among the effectiveness variables, commitment to company, as expected, has a significant negative path to willingness to turnover, and a positive but weak path to change in performance. Change in performance positively relates to overall performance, as predicted.

5. Discussion of results

Fig. 2 depicts the direct influences of the three non-HR contextual organizational elements on the knowledge work behaviors and knowledge outcomes. Coupled with paths within and between knowledge work behaviors and knowledge outcomes (see Fig. 4), Fig. 2 also implies many indirect paths. Direction and performance information has the strongest set of paths through the knowledge system. It relates directly to three of the knowledge work behaviors and indirectly, through paths to using systematic processes and focusing on system performance, to the fourth, knowledge linking. It has several indirect paths to methods and processes improvements, and a particularly strong direct relationship and another indirect path to organizational clarity. On the other hand, it has only weak indirect paths to effective knowledge generation and use. Thus, the presence of direction and performance information seems primarily to broaden what people attend to in their work and how they go about solving problems and learning, but these business related frameworks only indirectly drive the linking of knowledge across the organization, its effective generation and use,

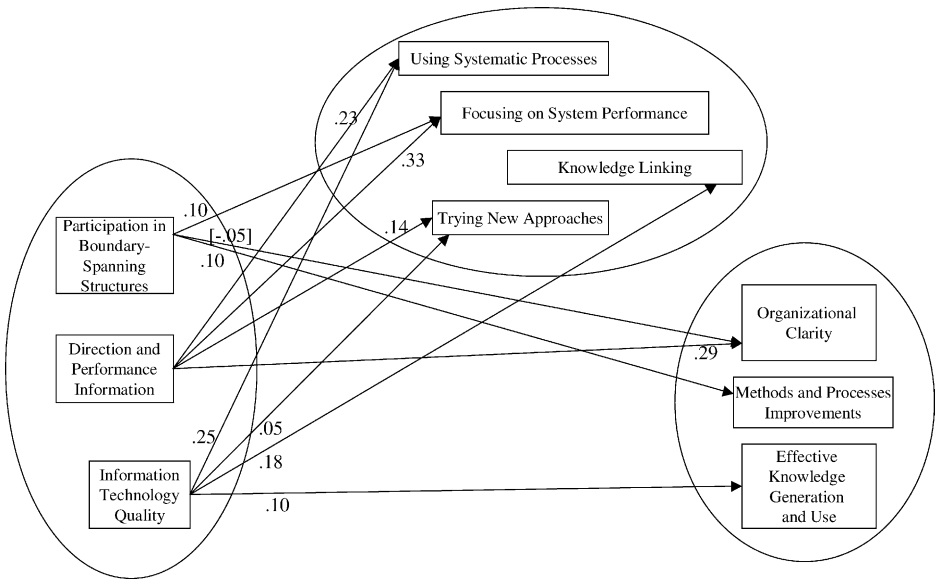


Fig. 2. Direct non-HR organizational contextual element influences on knowledge work behaviors and knowledge outcomes.

and improvements in methods and processes. This pattern of findings is consistent with Dougherty et al.'s (2000) observation that in innovative firms, people "telescope" (p. 335) back and forth between what they call the "standardizing priorities" of the business as a whole with many NPD endeavors and market forces to contend with and the idiosyncratic, situated requirements of their particular NPD task.

The results support the perspective that IT is an enabler of the work of the knowledge system, but that it is a tool for, not the solution to, the problem of how to manage knowledge (e.g. Anand et al., 1998; Davenport and Prusak, 1998). It operates primarily by enabling the using of systematic processes and the linking of knowledge.

Given the emphasis in the literature on the creation of cross-functional teams for NPD, the most surprising finding of the study is the relatively weak role that participation in boundary spanning structures plays in the knowledge system. Its only direct impact on knowledge work behaviors is to focusing on system performance. Through this path it indirectly relates to knowledge linking, but it is surprising that it does not have a direct path to knowledge linking. Apparently working in formal groups for various purposes does not necessarily link knowledge across the organization, which may confirm the viewpoint of scholars who have found emergent rather than formal networks to be the most powerful stimulus to knowledge sharing (e.g. Brown and Duguid, 1991; Wenger, 1998). However, through its (weak) direct links to focusing on system performance and to methods and processes improvements, participation in boundary-spanning structures has indirect paths to effective knowledge generation and use. These findings suggest that the value of participating in boundary spanning structures may be less in knowledge exchange among participants and more in knowledge combination—combining the perspectives and knowledge frameworks of the participants into new knowledge (Nahapiet and Ghoshal, 1998). The latter is much harder to accomplish, and may occur best through interpersonal working relationships. The slight negative relationship between participation in boundary spanning structures and organizational clarity supports previous work that finds that cross-functional teams often suffer from unclear reporting relationships and authority (Mohrman et al., 1995), which may explain why such participation does not have strong paths through the knowledge system.

Fig. 3 depicts the influence of the human resource practices on knowledge work behaviors and knowledge outcomes. Confirming the competitive importance of human capital (knowledge resources in the form of skilled and knowledgeable employees) in the knowledge enterprise (DeNisi et al., 2003), developmental emphasis has the most paths through the model of any of the contextual organizational elements. This also supports Cohen and Levinthal's (1990) notion that the patchwork of individual capabilities determines the organization's absorptive capacity—its ability to make sense of, learn about, and adopt new approaches. Developing employees, through formal developmental experiences, mentoring, and job experiences, expands their capacity for individual and collective sensemaking by exposing them to new formal knowledge and to tacit knowledge gained from experience.

In contrast, the compensation system variables have fewer and generally weaker paths through the knowledge system. Both organizationally and individually based pay weakly predict trying out new approaches. But they apparently provide opposite incentives for knowledge linking, with individually based pay negatively relating and pay based on organizational performance positively relating to this behavior. These findings support the emphasis by Moran and Ghoshal (1996) on creating a motivational environment that supports

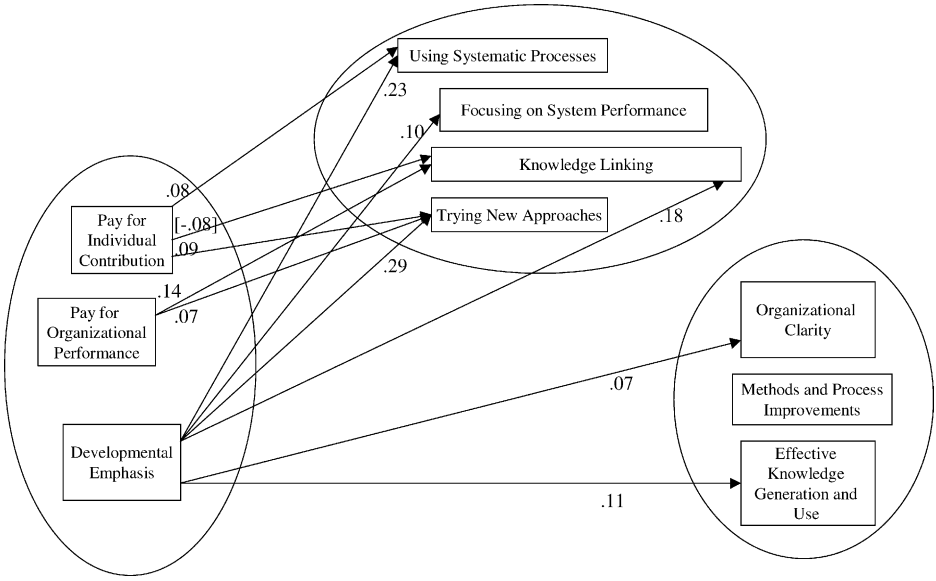


Fig. 3. Direct HR practices influences on knowledge work behaviors and knowledge outcomes.

exchange and interaction among employees by making it possible for employees to experience some of the new value that is created through successful knowledge management in the organization.

Fig. 4 depicts the significant paths among knowledge work behaviors and knowledge outcomes. Of particular interest is the central role that procedural knowledge plays in the knowledge system through the using of systematic processes. In addition to its direct links to organizational clarity, methods and processes improvements, and overall performance (depicted in Fig. 6), this behavior indirectly impacts all of the knowledge outcomes through its strong paths to the other three knowledge work behaviors. Apparently knowledge is more likely to be linked, focus to be elevated, and new approaches to be tried, if systematic processes frame the way knowledge work is carried out. This is consistent with the qualitative findings of Leonard-Barton (1995) and others that learning and innovation are competencies that can be built into organizational processes. The very strong link of using systematic processes to organizational clarity suggests that these processes also help employees make sense of the organization, how it operates, and what it is trying to accomplish.

Focusing on system performance leads both to methods and processes improvements and to knowledge linking, which, in turn, leads to effective knowledge generation and use. This again, is consistent with the notion that knowledge creation depends on the breadth of knowledge attended to.

Together, the knowledge work behavior results provide strong support for findings from earlier studies (Cohen and Levinthal, 1990; Szulanski, 1996) that the breadth of focus and the procedural knowledge that systematically guides how problems are approached are prime enablers both of the capacity to absorb various knowledge frameworks, and of its

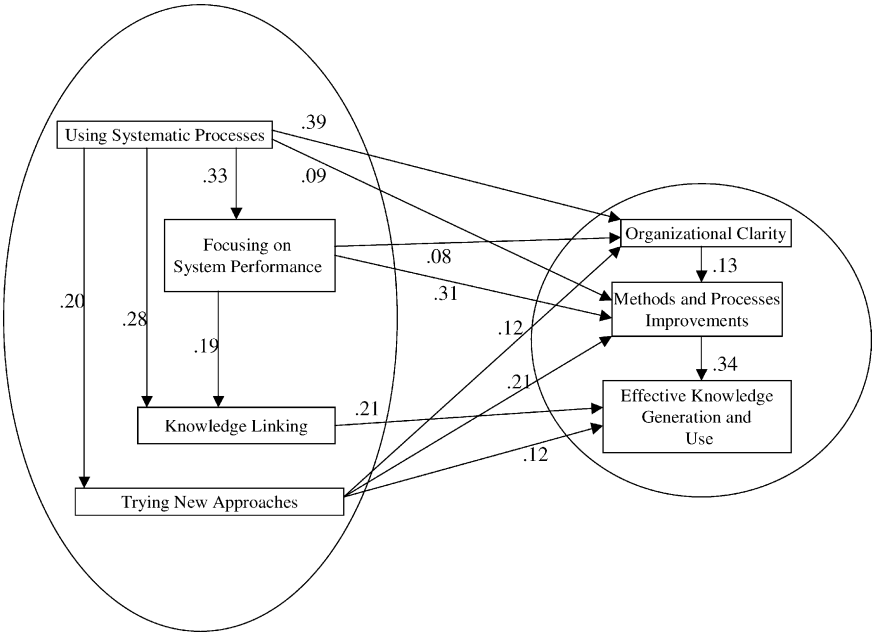


Fig. 4. Knowledge work behaviors and knowledge outcomes.

application in new approaches. Trying new approaches is the only knowledge work behavior with significant paths to all three knowledge outcomes, confirming the centrality of learning through experience and experimentation to knowledge outcomes in NPD settings.

However, given the large amount of attention paid to knowledge transfer and knowledge sharing in the knowledge management literature (e.g. Argote and Ingram, 2000; Dixon, 2000), knowledge linking plays a surprisingly constrained explanatory role in the knowledge system. It relates solely to effective knowledge generation and use. On the other hand, it is explained by many paths both from other knowledge work behaviors as well as from several contextual elements. Most of these contextual elements and knowledge work behaviors also have significant paths to other important variables in the knowledge system. Thus, the variables that impact knowledge linking have more of a subsequent impact than the knowledge linking itself. This same dynamic may characterize knowledge management programs and research that focus primarily on making knowledge available. Subsequent knowledge and performance outcomes attributed to knowledge linking may, in fact, be impacts of the mechanisms used to establish the links. Using systematic processes and focusing on system performance, in particular, are variables (as we measure them) that not only foster knowledge linking but also imply the existence of collective sensemaking. Knowledge linking behavior may be a necessary component of the knowledge system but in and of itself it may have a narrow impact on knowledge outcomes and performance that is probably not sufficient without concurrent collective sensemaking.

Fig. 5 shows the paths that lead directly to the employee outcomes. There is a mercenary side to both commitment and willingness to turnover. Pay based on organization

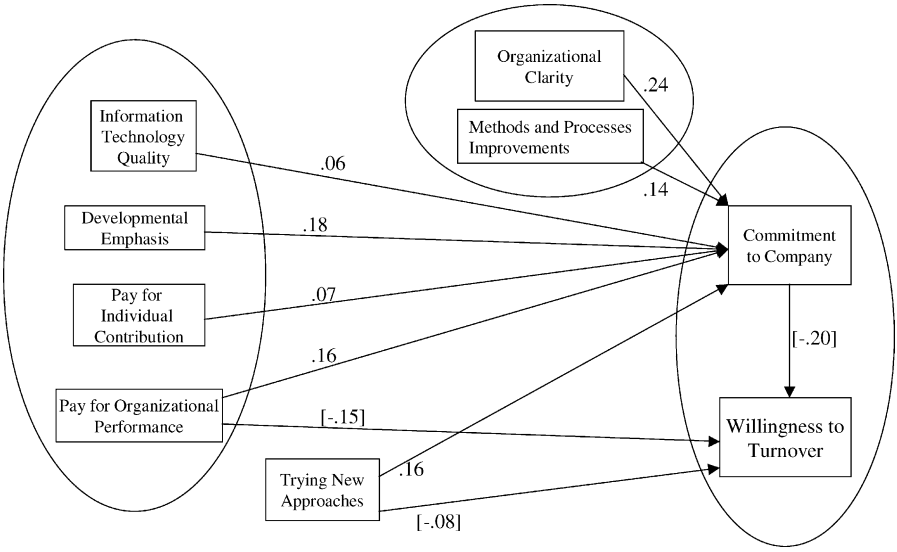


Fig. 5. Direct determinants of employee outcomes.

performance and, more weakly, pay based on individual performance, can build commitment to the organization. Pay for organization performance also reduces willingness to turnover, thus legitimating some compensation tactics for retaining knowledge.

More importantly, however, the findings that developmental emphasis, trying new approaches, organizational clarity, and methods and processes improvements are all strong predictors of commitment to company suggest that learning and development are more integral to the scientists' and engineers' affective attachment to the company (Finegold et al., 2002) than compensation. Knowledge and meaning are socially created as employees work in new assignments, face new problems, try out new approaches, make improvements, and develop new skills. The knowledge that is created becomes embedded in beliefs and actions, including employees' affective attachment to the organization. The direct and the numerous indirect paths from developmental emphasis to commitment, coupled with commitment's significant path to willingness to turnover, suggest that the same HR strategies that help build knowledge are the most important in retaining it.

Fig. 6 presents all the direct paths to the organization performance variables. Clearly the knowledge outcomes as a group have the most immediate and strongest relationships. Once again, however, using systematic processes and focusing on system performance single themselves out, this time by their direct path to overall performance (in addition to their myriad indirect paths to both performance measures). Evidently, these knowledge work behaviors lead to performance independently of their knowledge outcomes. Most likely this is because these two knowledge work behaviors are consistent with organizational values and priorities even if no innovations are involved and even if no greater organizational clarity results. Nevertheless, in our model, it is almost solely through knowledge outcomes that performance can be changed.

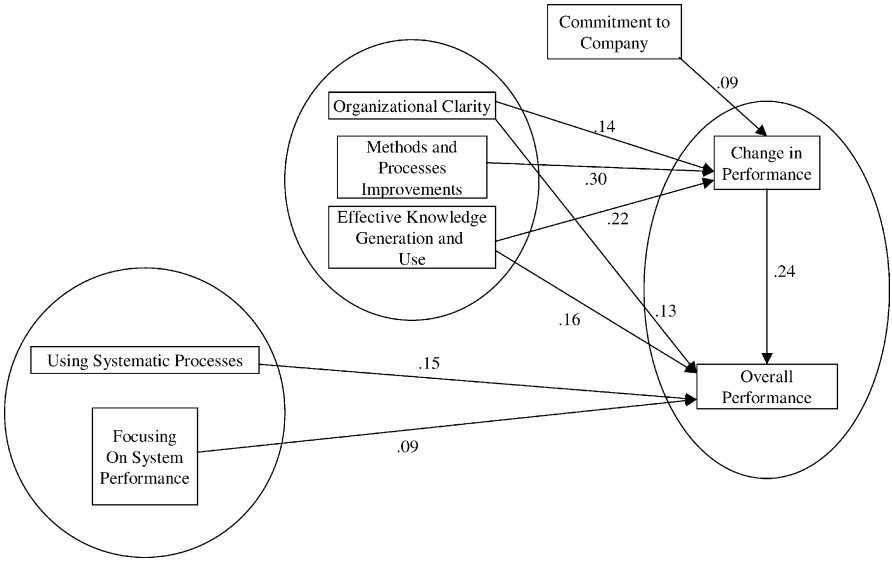


Fig. 6. Direct impacts on organizational performance.

6. Conclusions

This study has confirmed the importance of many streams of theoretical and empirical study. It has provided quantitative evidence that the knowledge and knowing capabilities of the firm—its intellectual capital (Nahapiet and Ghoshal, 1998)—do indeed translate into NPD firm effectiveness in the marketplace. It has shed light on the relative impacts of a number of variables that have not been simultaneously examined in the past. It demonstrates the importance of taking a systemic approach, if we are to understand how various elements of the knowledge system fit together to yield knowledge and business outcomes. For example, the somewhat surprising findings of the limited paths that are initiated by participation in boundary spanning structures and by knowledge linking indicate that the effectiveness of these much touted approaches depends on additionally incorporating the linked knowledge and expanded perspectives into the sensemaking processes that constitutes NPD work. Both may best be described as “necessary but not sufficient”.

Taking the perspective that knowledge work is sensemaking and that the resultant knowledge and its uses are social constructions, we have focused on knowledge work behaviors that contribute significantly to knowledge outcomes. Their centrality in the model, theoretically and empirically, indicates that future work on managing the knowledge enterprise cannot afford to neglect the knowledge work behaviors that are normative in the organization—and especially the extent to which systematic processes guide the work.

One of the primary ways that management can impact work behaviors is through the design of the contextual organizational elements. Our study has found that the design features that have received the most attention—IT, boundary spanning structures, and rewards—

have surprisingly limited, though some statistically significant, paths through the knowledge system.

Fortunately, the two design variables over which all managers have the most direct control are strongly related to the effectiveness of the knowledge system. Providing direction and performance information and emphasizing development ultimately have relatively large and pervasive paths to the effectiveness of the knowledge system. These design elements provide: (1) information to help people make sense of how their work fits into the larger system so they can direct their activities toward organizational requirements; and (2) opportunities for employees to broaden their knowledge and experience so they can bring more knowledge to bear in approaching their NPD work.

The finding that organizational clarity is knowledge that is created as employees do their NPD work, and the strong relationship of organizational clarity—along with methods and processes improvements, developmental emphasis, and trying new approaches—to commitment, suggest that organizations would benefit were managers to better understand that work experiences are the primary source of the development of human capital, and also the source of meaning that leads to affective attachment to the firm. Strategies to retain and build human capital that rely primarily on attracting and rewarding talented employees may not result in long-term social or human capital development, no matter how logical they seem and no matter how popular they are.

This research has a number of limitations. First, the companies in this study were all mature companies engaged in large system development. They have long development cycles, rely on very deep technical expertise, and face huge challenges integrating the work of large teams. These settings may require more collective sensemaking and shared understanding than other kinds of NPD settings. In addition, they are populated by a mature workforce compared with high tech start-ups. This model definitely needs to be tested and most probably refined in different kinds of NPD settings.

Given the complexity of our systems model, we focused initially on the internal aspects of the system and did not include connections to external knowledge or to external stakeholders such as suppliers, customers and partners. A complete model of the knowledge enterprise would be as an “open system”, and include external linkages.

We operationalized many of the constructs in the study with previously untested measures, and shortened some existing measures to keep the instrument to a manageable size. It is possible that with better measures, some of the findings would change. But the fits of this model to the two data samples suggest that the changes will be in the particulars, not in the overall patterns and paths.

The data used to test the model all come from the same instrument, so these findings are subject to the problems of common method bias. We see all aspects of the system through the eyes of the employee. On the positive side this means that we are capturing the sense that the employee has made of the system, which is congruent with our theoretical perspective. On the negative side, the fact that all responses come from the same instrument inflates the relationships between variables. In our view, it is particularly problematic that we do not have objective measures of effectiveness and knowledge outcomes that are independent of the employee’s sense of the system. This probably leads to an overestimation of the explained variance in the knowledge outcomes and effectiveness variables.

Furthermore, although the respondent is asked to report on the work behaviors that are normative among the people she works with, we are unable to get a collective view of these behaviors. A follow up study carried out at the business unit level, exploring shared meanings and group level perceptions may yield a different system model. This would also allow the use of external and/or objective measures of effectiveness, since business results are delivered at the business unit level.

Despite these very real limitations, this research strongly suggests the usefulness of the essentials of the model. The results point out the need to emphasize the way in which work is carried out, rather than programs and particular approaches to managing knowledge. For researchers, this system model may serve as an integrative framework for the many diverse streams of research and theory that deal with the knowledge enterprise and with knowledge management. For managers, it offers insights into how to design knowledge and knowing capabilities into the fabric of the organization.

Acknowledgements

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Appendix A

A.1. Information technology quality

This scale is the mean of the responses to the following five items (alpha = 0.83).

Please indicate the degree to which you agree or disagree with each of the following statements about your organization (1 = *strongly disagree*, 2 = *disagree*, 3 = *neither*, 4 = *agree*, 5 = *strongly agree*).

- We have easy computer access to the information we need to do our jobs.
- We have state of the art computer tools.
- Our computer tools help people from multiple functions to work together effectively.
- We have excellent computer systems for coordinating with each other.
- Our information and computer systems are flexible.

A.2. Participation in boundary spanning structures

Respondent was given a score of 1 for each type of group he or she reported belonging to. Scale was calculated as the sum, ranging from 0 to 4 types of groups.

- Cross functional project or program teams.
- Problem-solving and improvement teams.
- Councils or committees.
- Knowledge-sharing networks.

A.3. Direction and performance information

This scale is the mean of the responses to the following seven items (alpha = 0.87).

How well informed are you about the following statements (1 = *not at all informed*, 2 = *somewhat informed*, 3 = *adequately informed*, 4 = *well informed*, NA = *not applicable*)?

- Company plans that affect you.
- Company goals.
- Company performance.
- The goals of the programs/projects you work on.
- The performance of the programs/projects you work on.
- Your unit's goals.
- Your unit's performance.

A.4. Developmental emphasis

The mean of the following three items (alpha = 0.73).

Please indicate the degree to which you agree or disagree with each of the following statements about your organization (1 = *strongly disagree*, 2 = *disagree*, 3 = *neither*, 4 = *agree*, 5 = *strongly agree*).

- We have a good process for mentoring technical employees.
- Developing employee skills is a high priority for managers in this company.
- My job assignments provide the opportunity to keep my skills and knowledge up to date.

A.5. Pay for organizational performance

Mean of the following three items, agree–disagree (alpha = 0.81).

- How much pay I receive depends on the success of our business.
- When this organization is successful, I share in the benefits.
- I share in the financial gains of the company.

A.6. Pay for individual contribution

Mean of the following three items, agree–disagree (alpha = 0.86).

- My pay level is determined by my individual work performance.
- My pay level is determined by my knowledge and competencies.
- My pay reflects the value I have helped create for the organization.

A.7. Focusing on system performance

Mean of the following four items, agree–disagree (alpha = 0.74).

- We regularly review how our unit is doing in achieving its business objectives.
- We have good understanding of the impact of our technical work on business performance.
- We routinely assess the impact of our technical work on overall product and process quality.
- We routinely track the impact of our technical work on cost.

A.8. Using systematic processes

Mean of the following five items, agree–disagree (alpha = 0.73).

- Our decisions are data based.
- We follow systematic processes for making decisions.
- We carefully evaluate the costs and benefits of alternatives.
- There are processes in place to learn from failures and from things that go wrong in projects.
- We have rigorous tools for making tradeoff decisions.

A.9. Knowledge linking

Mean of the following three items, agree–disagree (alpha = 0.66).

- We have systems that make it easy to find out lessons learned elsewhere in the organization.
- When we solve interesting problems we share what happened with others who might benefit.
- We maintain contact with people in other parts of the organization who can be a useful source of information, resources, and support.

A.10. Trying new approaches

Mean of the following five items, agree–disagree (alpha = 0.75).

- There is a willingness to try out new ideas.
- Finding a better way to do things is valued.
- New and different ideas are always being tried out.
- Little value is placed on ideas and approaches that are "not invented here" (reverse scored).
- There is very little risk-taking in this organization (reverse scored).

A.11. Organizational clarity

Mean of the following seven items, agree–disagree (alpha = 0.87).

- This organization has a clear strategic direction.

- The strategy of our organization is not well defined (reverse scored).
- Goals are well aligned in this organization.
- Priorities are well defined and communicated.
- Our team/unit's authority is well defined.
- Roles and responsibilities are clearly defined.
- We have a clear understanding of how the organization is intended to operate.

A.12. Methods and processes improvements

Mean of the following four items (alpha = 0.83).

In the past several years, how much has your unit accomplished the items below (1 = *no accomplishment*, 2 = *slight accomplishment*, 3 = *moderate accomplishment*, 4 = *a lot of accomplishment*)?

- Made improvements in our work methods and processes.
- Introduced better ways to organize ourselves.
- Improved the way we coordinate our work.
- Introduced better ways of managing cost and financial impact.

A.13. Effective knowledge generation and use

Mean of the following three items (alpha = 0.83).

How effective has your unit been in the following areas (1 = *not at all effective*, 2 = *slightly effective*, 3 = *moderately effective*, 4 = *effective*, 5 = *highly effective*)?

- Incorporating new knowledge, methods and inventions in its work.
- Generating new ideas, methods, processes, and applications.
- Reusing and incorporating knowledge from other projects and other parts of the organization.

A.14. Commitment to company

Mean of the following four items, agree–disagree (alpha = 0.79).

- I am proud to tell others that I am part of this company.
- I talk up this company to my friends as a great company to work for.
- I find that my values and the organization's values are very similar.
- This organization really inspires the best in me in the way of job performance.

A.15. Willingness to turnover

Mean of the following three items, agree–disagree (alpha = 0.68).

- It would be very difficult for me to change companies at this time (reverse scored).
- I would be willing to change companies for career advancement now.
- I would be willing to change companies for more money.

A.16. Change in performance

Mean of the following eight items (alpha = 0.86).

How has effectiveness in each of these areas changed in the past several years (1 = *declined*, 2 = *somewhat declined*, 3 = *stayed the same*, 4 = *somewhat increased*, 5 = *increased*)?

- Cost effectiveness.
- Financial performance.
- Productivity.
- Customer focus.
- Speed (e.g. cycle time, response time, time to market).
- Innovation.
- Technical performance.
- Quality.

A.17. Overall performance

Mean of the following eight items (alpha = 0.90).

Compared to what you think is possible, *estimate* how effective your unit is in each of the following performance areas.

Fill in the percentage in the space below (for example 80% cost effective means you have achieved about 80% of possible cost effectiveness).

- Cost effectiveness.
- Quality.
- Productivity.
- Customer focus.
- Speed (e.g. cycle time, response time, time to market).
- Innovation.
- Technical performance.
- Financial performance.

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