8-16-1996

The Role of Information Technology in Organizational Knowledge Creation for New Product Development

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Introduction

The importance of teams and cross-functional coordination and integration for new product development is widely recognized (Imai et al. 1985, Zirger and Maidique 1990, Wheelwright and Clark 1992, Ettlie 1995). Virtual new product development teams at Ford use worldwide talent and technology such as CAD/CAM, videoconferencing and simulations to share designs, and to build and test prototypes of a global car (Leonard-Barton 1992, Rayport and Sviokla 1995). Globally coordinated engineering-release databases, common CAD tools and a common repository of national environmental and safety laws eliminate redundant engineering efforts (Ives, Jarvenpaa and Mason 1993). Similarly, an intranet linking design centers in Asia, Europe and the U.S. facilitated development of the 1996 Taurus (Cortese 1996).

During new product development, global organizations need to communicate effectively across functional areas and with geographically dispersed sites. Organizations also need to integrate knowledge by coordinating across phases of new product development. Technically complex products drive organizations with specialized competencies to gain complementary skills by developing close relationships with suppliers and customers and even with competitors if necessary. Hence, IT has an important role to facilitate knowledge creation with communication and coordination across temporal, geographical, departmental and organizational boundaries.

Knowledge Creation and Coordinating Mechanisms

The objective of this study is to (1) conceptualize a new framework by integrating frameworks on knowledge creation (Nonaka 1994) and interdependencies (Adler 1995), and (2) apply the new model to examine the role of information technology (IT) in new product development. Nonaka's framework has four modes (combination, internalization, externalization and socialization) based on the conversion between tacit and explicit knowledge. On the other hand, Adler's typology looks at three phases (pre-project, product and process design, manufacturing) in new product development and four coordination mechanisms (standards, schedules and plans, mutual adjustment and teams).

An Integrated Framework

Each of Adler's coordination mechanisms is particularly effective for a corresponding knowledge creation mode. By mapping the Nonaka and Adler frameworks to each other (see Figure 1), I propose an integrated framework of organizational knowledge creation in new product development. Following is the rationale based on the concepts of suitability of the coordination mechanism to the degree of novelty and knowledge tacitness. Tacit knowledge is subjective, encompasses perspectives, know-how, expertise and context specific skills (Winter 1987, Nonaka 1994, von Hippel 1994), with high needs for interactivity. Teams are an effective interactive cross-functional coordination mechanism (Adler 1995, Imai et al. 1985, Zirger and Maidique 1990, Wheelwright and Clark 1992, Ettlie 1995) for socialization to convert tacit knowledge into tacit knowledge that is more widely shared (Nonaka 1994) (see cell I in Figure 1). Mutual adjustment in design reviews is needed for externalization to make the widely shared tacit knowledge explicit (cell II in Figure 1). This explicit knowledge can either be converted to improved explicit knowledge by combination with existing knowledge, or improved tacit knowledge by internalization. Standards in the form of design rules facilitate combination (cell IV), while the feedback or sign offs from alternative plans assist internalization (cell III).

An Application of the Integrated Framework

To illustrate an application of the integrated framework, I analyze qualitative data on cases of specific IT used in the disk drive industry, drawing on over 60 interviews with executives at different organizational levels including the CEO, CFO, COO, CIO, marketing manager, engineering manager and plant manager. The executives were asked in semi-structured interviews how IT was contributing to performance improvements. Most of the interviews took place at pilot manufacturing plants and headquarter sites in the Silicon Valley California. The interviews were audio-taped and transcribed and collected as part of a larger study.

The Role of IT in Knowledge Creation

By mapping specific IT from the interviews to the proposed integrated framework, I demonstrate the usefulness of the model. I focus on four cells that best illustrate the role of IT, since completing all cells is irrelevant and beyond the scope of this short paper. First, I discuss cell IV of the integrated framework. IT readily represents explicit knowledge, which is objective and easy to encode, transformed to further explicit knowledge in the "combination" mode of knowledge creation (Nonaka 1994) and the "standards" type of coordination mechanism (Adler 1995). For example, an engineering manager, whom we interviewed at organization A, explained how design engineers input information with a special language that uses equations to specify the circuit requirements. The request is compiled with circuit standards in a CAD library to generate a code that will synthesize the circuits by figuring out where the interconnector, flip-flops, gates and other components are connected together. In another example, pre-defined rules in product data management systems (PDMS) automatically route design documents for electronic signature approvals through email regardless of geographic location.

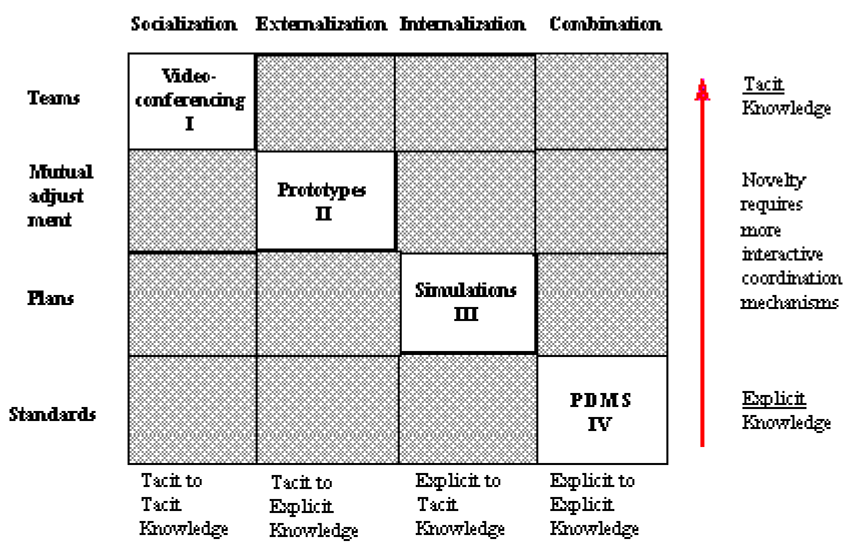

Figure 1. Organizational Knowledge Creation in New Product Development Framework with potential IT cases

At the opposite extreme for interactivity, (see cell I in Figure 1) a "socialization" knowledge creation mode (Nonaka 1994) and "teams" type coordination mechanism (Adler 1995) usually require face-to-face interaction for the transfer of tacit knowledge which is difficult to articulate, communicate, formalize and encode (Winter 1987, Nonaka 1994, von Hippel 1994). Nevertheless, videoconferencing is being used successfully to substitute for or complement face-to-face because of its rich media, and interactive communication and coordination capabilities that cross geographical, departmental and organizational boundaries and the feasibility of ".. getting a lot more people involved..". The previous and following quotes reveal top management's perspective from firm B.

"There is something to say about physical interaction and visibly seeing people and actually being able to share.. You see the folks in the meeting and their reactions and responses and you also see the document that's being discussed." ..."So you're able to initiate a lot of communication, look at a lot of issues, ... and interrelate personally with people, because you can see the person and go back and forth and talk about it... To me, as companies become more global, it's really critical to run global operations to be able to have these sorts of communications ... "

The "internalization" knowledge creation mode (Nonaka 1994) depends on experimentation with multiple "plans" (Adler 1995) (see cell III in Figure 1). Computer simulations help engineers convert explicit knowledge (originating across boundaries) to tacit knowledge with many iterations of "what if" scenarios. Engineers vary parameters and test performance creating new knowledge without the need to build physical models. An engineering manager from firm C explains: "..they have the tools to tweak it and tune it where before they were just looking at masses of data and trying to figure it all out."

In contrast, models which are physical or virtual enhance the "externalization" knowledge creation mode (Nonaka 1994) by making tacit understandings of specifications explicit. The prototype becomes a source of discussion for "mutual adjustment" (Leonard-Barton 1988) coordination mechanisms (Adler 1995) and prevents misunderstandings from perpetuating (see cell II in Figure 1). Design reviews are more productive when producibility issues are addressed as the model uncovers problems. Files produced from two dimensional CAD drawings are used as input to stereolithography equipment which automatically generates a solid model by building up layers of plastic material. An engineering manager from firm D expresses his appreciation for a three dimensional physical prototype.

"... It saves a ton of time and it's intuitive. You know, when you've got drawings and you're trying to work things out, it's laborious. When you can actually make a thing, albeit plastic, and check that everything goes together and all kind of fits, the human brain is far better at saying, "Hey, this feels right," than looking at all these twenty-seven hundred drawings. You actually can intuitively say, "This is nice." And you can get a guy like me, who's not a mechanical engineer by trade, and say, "Boy, I think you've got a problem with this feature or that feature." You can have a much higher level of discussion. Instead of getting yourself roped in with drawings and suddenly there's, you know, a hundred and fifty thousand dollars been spent on casting tools and it isn't any good."

Implications

Based on Nonaka's and Adler's frameworks, I present an integrated framework of organizational knowledge creation in new product development and three hypotheses for future research: (1) in new product development a role of IT is to facilitate internalization, socialization, externalization and combination knowledge creation modes; (2) another role of IT in new product development is to facilitate teams, plans, mutual adjustment and standards (design/manufacturing coordination mechanisms in the product and process design phase); (3) there is a corresponding relationship between Nonaka's four knowledge creation modes and Adler's four coordination mechanisms in the product and process design phase.

As management gains increased awareness of the concepts of tacit knowledge and coordination mechanisms, they understand (1) that IT enables all modes of knowledge creation and is not limited to explicit knowledge transfer; (2) the importance of choosing appropriate IT to facilitate virtual boundary spanning in the global new product development process; and (3) that richer, more interactive media are needed for the transfer of tacit knowledge, which is difficult to encode and capture in an information system. Examples of suitable IT for each mode of knowledge creation and for each corresponding type of coordination mechanism, in the product/process design phase of new product development, are identified in this study and presented in an integrated framework. In the future, technology advances such as virtual reality will yields alternatives for rich media.

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