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The influence of deliberations on learning in new product development teams

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Abstract

Organizational learning in new product development involves the development of a knowledge base that can inform technical problem solving and decision making. We contend that learning processes in new product development can be studied by examining deliberations, that is, the patterns of exchange and communications which RD&E personnel engage in as they attempt to reduce the equivocality of problematic topics. This action research study examines how the management and design of deliberations enabled and obstructed learning. Using a blend of quantitative and qualitative methods, two knowledge intensive product development projects of equal technical complexity were studied. Factor analysis of barriers which obstructed knowledge development yielded four factors: knowledge sharing and planning barriers, knowledge frame of reference barriers, knowledge retention and procedural barriers, and a knowledge acquisition barrier. In addition, content analysis of interview data identified eleven categorical forces which enabled and disabled product development team learning. The results show that barriers and obstructions to product development team learning are linked to poorly designed and mismanaged deliberations. The results also suggest that learning in complex new product development projects is enabled by deliberations which are organized into small and informal forums; are conducive to knowledge sharing and active inquiry; which expose more people to the "big picture" of how the overall product system functions; and which utilize a participative approach to decision making. We conclude by discussing the managerial and research implications of these findings.

Keywords. Organizational learning, Sociotechnical systems, Nonroutine work, Deliberations, Product development, Action research.

1. Introduction

Our clinical observations suggest that the process of managing RD&E is strikingly similar to the experimental activities involved in the synthesis of a new chemical compound. Complex technologies and diverse specialists are like chemical molecules and free agents that require development, synthesis, and integration in order to add value to the user. Likewise, new product development is essentially a knowledge development and knowledge synthesizing activity consisting of a stream of routine and nonroutine tasks, performed by an array of individuals and groups. Complex new product development, like chemical synthesis, is inherently an orderly and disorderly process. In fact, the management of RD&E in new product development has been characterized as maintaining a balance between order and disorder (Quinn, 1985; Nonaka, 1988). More importantly, our characterization of the management of RD&E as an experimental activity necessarily implies that organizational learning processes are involved. Especially for new product development organizations in high-velocity environments, maintaining a dynamic balance between order and disorder requires the ability to learn and unlearn (Hedberg, 1981; Imai et al., 1985).

Conceptualizations of organizational learning, based on several reviews of the literature, are diverse and numerous (Fiol and Lyles, 1985; Levitt and March, 1988; Huber, 1991). The range of existing conceptualizations have focused primarily on organizational learning: as adaptation; assumption sharing; development of a knowledge base; or as institutionalized experience (Shrivastava, 1983). However, because new product development is highly knowledge-intensive, we have chosen to focus attention on conceptualizations which view organizational learning as the development of a knowledge base (Duncan and Weiss, 1979; Lundberg, 1989).

In knowledge-intensive organizations, competitive advantage is a derivative of organizational learning, that is, how quickly and effectively members are able to organize, develop and utilize their internal knowledge base (Stata, 1989; Meyers, 1990; Brown, 1991). According to Stata (1989), organizational learning develops through the process of sharing insights, knowledge and mental models, while building on past knowledge and organizational memory. In a similar vein, Nonaka and Johansson (1985, p. 183) describe this as involving "...an organizational process where individual knowledge is shared, evaluated and integrated with others in the organization". Moreover, organizational learning is an organizational process as opposed to merely the collection or summation of individual learning experiences (Shrivastava, 1983). While individuals are the agents through which organizations learn, individual learning must be communicable, shared publicly, and integrated for it to become "organizational" (Duncan and Weiss, 1979; Nonaka and Johansson, 1985). Communication, knowledge sharing and information distribution processes are instrumental for making individual insights and know-how accessible to others (Jelinek, 1979; Nonaka and Johansson, 1985; Huber, 1991). Further, information must not only be accessible if it is to be used by others, but it must also be accepted and validated. Acceptance and validation of information accessed from highly differentiated yet reciprocally dependent subunits or individual specialists is facilitated by interactive (Quinn, 1985) and relational (Pava, 1983) learning processes that enable debate, clarification, and varied interpretations (Daft and Lengel, 1986; Huber, 1991). However, the "thoroughness" (Huber, 1991, p. 60) of organizational learning is dependent upon the integration of multiple and inherently divergent perspectives (Kanter, 1988). Duncan and Weiss (1979, p. 86) summarize this process as one in which:

> "The overall organizational knowledge base emerges out of the process of exchange, evaluation, and integration of knowledge. Like any other organizational process, the only actors involved are individuals. But it is a social process, one that is extra-individual. It is comprised of the interactions of individuals and not their isolated behavior."

This view suggests that organizational learning does not occur unless knowledge is developed. In other words, knowledge is the outcome of organizational learning processes. Knowledge as outcomes may include new formulas, specifications, theories, procedures, or typologies. More specifically, it is through the above mentioned processes of social interactions and exchange that "...knowledge about action-outcome relationships and the effect of the environment on these relationships is developed" (Duncan and Weiss, 1979, p. 84). Changes in states of knowledge as an outcome suggests that organizational learning processes are simultaneously both interactive and interpretative, social and cognitive.

2. Conceptual framework

2.1. Learning systems in new product development

Research and development is intrinsically a learning system (Carlsson, et al., 1976). According to Shrivastava (1983, p. 14), "learning systems are the mechanisms by which learning is perpetuated and institutionalized in organizations". In this research setting, learning systems are the formal and informal mechanisms which new product development team members use during the process of knowledge development. Such mechanisms may include methods for detecting, storing, and retrieving new team learning (Meyers and Wilemon, 1989).

New product development team members also rely upon learning systems for making critical decisions and for detecting and correcting errors (Duncan and Weiss, 1979). Product development efforts can be delayed or even fail if errors in the early stages are either ignored or undetected. Meyers and Wilemon (1989), for example, found that technology development teams that never felt free to allocate time to learning in the initial stages of development were more likely to encounter repeated errors and mistakes downstream. A failure to detect errors is costly, especially when problems with a product are identified after prototypes have been scaled-up or advanced into manufacturing — usually with disastrous results. Similarly, product development efforts are also thwarted when problems take too much time to fix. Knowing what caused a problem (error detection) is useful only when someone takes action to prevent its reoccurrence (error correction). Hence, the ability to detect and correct errors in a timely manner is dependent on effective new product development team learning systems.

2.2. Deliberations in new product development

New product development team learning systems must manage both information processing and information interpretation activities (Tushman and Nadler, 1980; Nonaka and Johansson, 1985; Weick, 1991). Previous sociometric research has shown that RD&E performance is contingent on an organizational subunit's capacity to provide the necessary information amount in order to reduce work-related uncertainty (Allen et al., 1979; Tushman, 1979). However, organizational subunits with a sufficient amount of information must also have the capacity for interpreting such information — especially when equivocality is high (Daft and Lengel, 1986).

While the majority of the RD&E information processing literature has focused on "gatekeeper engineering" (Davis and Wilkof, 1988), few studies have examined how the management and design of deliberations influences learning in knowledge-intensive organizations. As Tornatsky et al. (1983) point out in their review, most research in this area has been limited to analyses of sociometric links, which amounts to studying the residuals of information exchange relationships, rather than focusing on the discrete relations embodied by those links.

In contrast, this study examines what Pava (1983) refers to as deliberations which occur over the course two concurrent new product development projects as a means for identifying factors that influence knowledge development. Pava (1983, p. 58) defines deliberations as:

> "...reflective and communicative behaviors concerning a particular topic. They are patterns of exchange and communications in which people engage with themselves or others to reduce the equivocality of a problematic issue."

Pava (1983) offers further clarification, specifying that a deliberation is identifiable by the existence of an equivocal topic (the issue, problem, or decision that needs to be addressed), which is explored or addressed in a particular type of forum (the location, ground rules and norms for exchanging information), composed of interested parties (the people involved). Furthermore, a deliberation differs from a discrete decision or project milestone in that it encompasses the informal human interactions and the continuous ebb and flow of information related to a particular topic over time (Pava, 1986; Purser and Pasmore, 1992). Deliberations within this framework represent the socio-cognitive artifacts of intensive, nonroutine technology (Tornatsky et al., 1983; Trist, 1983).

Weick (1979) also emphasizes that uncertainty triggers organizing around equivocal topics. Accordingly, Weick (1979, p. 47) notes that organizing:

> "...involves a grammar, code, or set of recipes. ...and it involves arranging processes to cope with the equivocal nature of streams of experience. The processes themselves are also streams. They are social and involve multiple actors."

In product development, nonroutine tasks that are high in complexity and uncertainty (Perrow, 1967) trigger organizing processes to deal with equivocal problems which cannot be solved by any single person or function (Pava, 1983). Hence, reliance upon the formal organization is often inadequate for learning how to resolve equivocal problems associated with nonroutine tasks (Galbraith, 1977; Pava, 1983). In response to coping with the equivocality and multiple conversion streams characteristic of nonroutine tasks, emergent deliberations rely on rich media (Daft and Lengel, 1986), involving multiple and temporary actors which transcend static and formal organizational boundaries (Pava, 1983). In addition, Brown and Duguid (1991) describe innovative learning systems as those which sanction deliberations that are already embedded within informal, emergent, and fluid "communities-of-practice". Moreover, highly fluid and emergent "task-dominant" modes of organizing have superior integrating and knowledge synthesizing capabilities when uncertainty is high (Souder, 1987, p. 233).

Clearly, deliberative processes are operative within different formal organizational structures. Whereas former research has focused on delineating the contingencies for determining the optimum formal organizational structure (Burns and Stalker, 1961; Lawrence and Lorsch, 1967; Allen, 1986; Allen and Hauptman, 1987), we are more concerned with understanding how the management and design of deliberations influences knowledge development and learning within different organizational structures. This view of learning, is, as Shrivastava (1983, p. 14) points out, "...closely linked with organizational sense-making processes which are basically interpretive routines used by decision-makers to detect problems, define priorities, and developed an understanding of how to deal with performance discrepancies." More importantly, this view suggests that sense-making processes can potentially have either an enabling or disabling influence on learning (Shrivastava, 1983, p. 14).

We propose that high performance learning systems in new product development will be characterized by deliberations that enable organizational members to acquire, share, interpret and retrieve the knowledge that they need for resolving equivocal problems. More specifically, this field study was conducted to explore the following research question:

What factors associated with the management of deliberations enable (or obstruct) learning and knowledge development in new product development teams?

3. Research methods

3.1. Research setting

This study was conducted in a research and development division of a Fortune 1000 firm which is a manufacturer of consumer and industrial products. This company is primarily technology-driven and has a heavy investment in RD&E. To describe the research setting, subjects of this study evolved out of a strong entrepreneurial culture with a track record for introducing radically innovative products into the market. However, the Director of R&D considered the learning systems within product development to be outmoded and in need of revitalization. The Director was also concerned that relatively few technical professionals in his division were aware of customer needs or knowledgeable of the product system architecture. One reason is that most product development projects were organized into large, centralized, functional-matrix programs. Recognizing these shortcomings, the Director of R&D initiated a sociotechnical system change effort for redesigning the division.

3.2. Action research method

This study utilized multiple data collection methods and investigators to understand how deliberation processes influence learning in new product development. Because we were interested in producing knowledge which was useful to both theory and practice (Cummings and Mohrman, 1985), we employed the action research method (Susman, 1983; Weisbord, 1987; Whyte, 1991), which purposely maximized the involvement of professionals in helping us in the design of the methods, collection, and analysis of the data. Given the fact that our investigation would be examining how scientists performed their work, and given the difficulties inherent in securing the cooperation of highly autonomous professionals, we invited R&D personnel to become co-inquirers and active partners with us in the design and administration of the study. Besides allowing us to gain access to insider knowledge (Evered and Louis, 1981) about the product development process, the action research method also allowed R&D personnel to participate in an organizational self-appraisal of their own organizing and learning processes (Huber, 1991; Morgan and Ramirez, 1983).

3.3. Research design

Utilizing the action research method, a special task force consisting of eight R&D professionals were put on full-time special assignments for a year to work in collaboration with us on the study and sociotechnical systems redesign effort. The sociotechnical systems methodology consists of three analytical phases: the environmental, social, and technical system analyses (Pava, 1983; Pasmore, 1988). The environmental analysis identifies current and future stakeholder demands and assesses how effectively such demands are being met. This assessment ultimately identifies needed changes in organizational design in order to effectively respond to anticipated future demands. The social system analysis is an assessment of peoples' attitudes, values, roles, work climate and job design. The technical system consists of the tools, techniques, devices, methods, procedures and knowledge used in the design or production process. The routine technical system analysis typically identifies variances in the work flow by examining the process by which the organization acquires inputs, transforms inputs into outputs, and provides outputs or services to clients or customers. Although data were collected and analyzed for each of the three subsystems within the sociotechnical systems framework (environmental, social, and technical systems), this paper is limited to the results derived from the deliberation analysis of the organization's nonroutine technical system.

Ten additional R&D professionals were also recruited on a part-time basis to assist in the data collection. We used multiple data collection methods which included conducting 55 structured interviews and the administration of a questionnaire to 130 R&D professionals.

3.4. Data sources/project selection

The task force selected two concurrent projects in the division as data sources for the study. The Aim project was chosen because it represented the core technology and largest new product development program in the division. Approximately 150 people in the division charged the majority of their time to this project. The Aim project was initiated as a product improvement program.

In contrast, the Blitz project represented a new strategic use of technology in the company, and was a radical innovation; it was new to both the company and the market. The Blitz project was also the first significant market-pull innovation for the R&D division. While only 30 people in the R&D division were assigned to the Blitz project, their interfaces with other divisions involved in the product's development were frequent and extensive. More importantly, the Blitz project was also chosen because it represented an administrative innovation. In contrast to the large functionalized-matrix organization of the Aim project, the Blitz project was essentially a self-organizing new product development team.

3.5. Field interview questions and data collection

All eighteen R&D professionals received 20 hours of training in interviewing skills and education related to the nonroutine technical system analysis methods. The nonroutine technical system analysis consists of identifying deliberation topics, evaluating how topics are explored in forums, and examining the configurations of parties involved in the exchange of information. Subjects who had been closely involved in deliberations throughout each of the projects were identified. Thirty-four subjects who were identified as instrumental to the development of the Aim project, and 21 subjects who were involved in deliberations during the Blitz project were interviewed. This resulted in a total sample of 55 interviews ($N=55$).

Exploratory interviews were conducted in tandem, with one task force member responsible for asking questions, and the other for taking notes. The interview followed a structured protocol, consisting of 11 open-ended questions. The interview question format probed subjects to identify critical incidents relevant to the deliberations they were involved in. This included asking subjects to describe: the equivocal problems which were topics of discussion; the forums where topics were discussed; and how people who were involved in the deliberation influenced discussions. Subjects were also asked to identify any barriers, impediments, or information gaps which obstructed the knowledge development process. Interviews lasted approximately 90 minutes; in total, 175 pages of transcripts were generated.

General categories descriptive of enabling and disabling forces for team learning from the interview data were developed by the first author. Content analysis of the interview responses were then sorted independently by two separate coders into the associated categories. The coders achieved a minimum of 83% agreement on the classification of categorical responses.

3.6. Questionnaire administration and measures

Based on a preliminary analysis of the interview data, the authors and task force generated seventeen questionnaire items which were descriptive of knowledge development barriers in new product development (see the Appendix). Subjects were asked to rate the extent to which each item was experienced as being problematic or a barrier to knowledge development in deliberations on a 7-point response format ranging from "To no extent" to "To a great extent".

To assess if the two projects varied in levels of technical complexity and nonroutine task characteristics, we administered two other scales. Using items developed by Souder (1987), the project complexity scale consisted of three questions pertaining to level of technical difficulty and technical complexity, which were also based on a 7-point response format.

Consistent with Perrow's (1967) theoretical construct, nonroutine task characteristics were measured by assessing the extent to which tasks were analyzable and frequency of task exceptions. Unanalyzable tasks lack objective computational procedures for guiding work activities (Daft and Macintosh, 1981). Similarly, task analyzability assesses the degree to which the conceptual knowledge is available (Souder, 1987). Analyzability is also linked to Duncan and Weiss' (1979) notion of knowledge of action–outcome relationships, or what Thompson (1967) refers to as knowledge of cause–effect relationships. We reframed our items which we derived from a scale developed by Withey et al. (1983) in language that was more fitting to the RD&E population. Specifically, six items were used to assess the level of prior conceptual knowledge of RD&E tasks. The six-item scale is scored so that the high score (7) reflects an unanalyzable set of tasks and lack of knowledge about cause–effect relationships.

Perrow (1967), Daft and Macintosh (1981), and Van de Ven and Delbecq (1974) have conceptualized task exceptions or task variability as the second conceptual dimension of nonroutine work. The notion of task exceptions signifies that a high frequency of novel or unexpected events occurs for which problems or solutions cannot be predicted in advance. A project characterized as high in task exceptions would imply that procedures and knowledge would have to be developed or invented in real-time in response to unexpected events and novel discoveries. Hence, task exceptions in RD&E are more a measure of the degree to which tasks are knowledge intensive. Task exceptions were measured using a three-item index derived from a modified version of a scale developed by Van de Ven and Delbecq (1974). A high response to this question (7) implies that tasks are highly knowledge-intensive, requiring the development of new procedures or knowledge.

Questionnaires were administered to a purposive sampling of 24 percent of the members from each project (Aim, $n=36$; Blitz, $n=7$). Survey respondents from Aim included the project manager, 3 group leaders, 4 supervisors, 21 scientists, 4 engineers, and 3 technicians. Survey data collected from Blitz subjects included the project manager, 5 scientists, and 1 technician. In addition, surveys were administered to technical support staff in the pilot plant, as well as a number of other R&D professionals who provided services to both the Aim and Blitz projects. In total, the survey was completed by 81 R&D personnel, yielding a 62 percent response rate.

3.7. Data analysis

In order to assess the construct validity of the scales employed, three factor analyses were undertaken. To decide the number of factors to be extracted, the latent root criterion was used with a minimum eigen value specification of one. The eigenvalue criteria of one is a well accepted standard when component factor analysis is chosen as the basic model (Hair et al., 1984). Principal component factor solutions utilizing varimax rotation were obtained for all three scales. Reliability analyses for all three scales were conducted. Analyses of variance (ANOVAs) were used to compare the two projects on knowledge development barriers, project complexity, and task nonroutineness.

4. Findings

4.1. Factor analysis

As shown in Table 1, four factors emerged from the factor analysis of the knowledge barrier items. The first factor, identified as *knowledge sharing and*

TABLE 1

Factor analysis of knowledge development barrier items[a,b]

Items[c]	Factor one	Factor two	Factor three	Factor four
	Knowledge sharing and planning barriers	Knowledge frame of reference barriers	Knowledge retention and procedural barriers	Knowledge acquisition barrier
1. Lack of knowledge	0.179	−0.028	0.084	**0.885**
2. Failure to utilize knowledge	**0.653**	0.152	0.196	0.288
3. Lack of knowledge sharing	**0.738**	0.316	0.091	−0.119
4. Lack of cooperation	**0.796**	0.383	−0.106	0.021
5. Language barriers	0.235	**0.617**	0.158	0.025
6. Missing parties	0.349	**0.628**	0.004	0.279
7. Wrong parties	**0.645**	0.074	0.353	−0.137
8. Lack of planning	**0.770**	0.192	0.233	0.149
9. Unrealistic timeframes	**0.574**	0.114	0.305	0.215
10. Unclear procedures	0.208	0.217	**0.668**	0.225
11. Lack of internal consulting	0.374	**0.507**	0.458	0.186
12. Lack of external consulting	0.149	0.263	**0.704**	0.056
13. Overstructured forums	0.093	**0.674**	0.139	0.057
14. Understructured forums	0.223	−0.123	**0.745**	0.083
15. Diffused responsibilities	0.256	0.416	**0.598**	−0.087
16. Lack of documentation	−0.201	0.263	**0.529**	0.463
17. Divergent values	0.186	**0.753**	0.189	−0.154
Eigen value	6.296	1.723	1.400	1.088
Variance explained	37.0	10.2	8.2	6.4

[a]$N=81$.
[b]Bold print highlights factor loadings with absolute values greater than 0.50.
[c]For a complete description of each item, see the Appendix.

planning barriers, included items such as lack of knowledge sharing, lack of cooperation, lack of planning and unrealistic time pressure. The second factor, consisting of language barriers, missing parties and divergent values, suggested that project members approached the task from dissimilar cognitive frames of reference; thus we named the factor, *knowledge frame of reference barriers*. Unclear procedures, diffused responsibilities, and lack of technical documentation capture some key issues related to the retrieval of past knowledge and procedures, and therefore the third factor was designated *knowledge retention and procedural barriers*. The fourth factor showed a very large positive loading of a single item, namely lack of knowledge, which we simply addressed as a *knowledge acquisition barrier*. Factor scores were computed by averaging all items falling within a particular factor. Reliability analysis of the knowledge barriers scale showed good internal consistency with a Cronbach alpha value of 0.89, well exceeding the 0.70 value recommended by Nunnally (1978).

The factor analysis of the project complexity scale elicited one factor (see Table 2). This factor, designated as *level of technical difficulty and complexity*, included items such as: extent project requires information and knowledge from different disciplines; extent technical goals and product specifications are challenging and difficult to meet; and extent product complexity is such that pieces can only be understood by those who are directly involved. Factor scores

TABLE 2

Factor analysis of project complexity items[a,b]

Items	Factor one Level of technical complexity and difficulty
1. The project being developed is complex in that it requires information and knowledge from many technical disciplines.	**0.914**
2. The technical goals and product specifications for this project are challenging and will be difficult to meet.	**0.909**
3. The project being developed is so complex that pieces of it can only be understood by the people who are directly involved.	**0.650**
Eigen value	2.08
Variance explained	69.4

[a] $N = 81$.
[b] Bold print highlights the factor loadings with absolute values greater than 0.50.

were computed by averaging across item scores. The Cronbach alpha for this scale was 0.72.

The factor analysis on nonroutine task characteristics elicited two factors (see Table 3). This two-factor solution confirmed our a priori assumption that there were two underlying dimensions. The first factor, designated as *level of prior conceptual knowledge*, included items such as: the extent know-how was

TABLE 3

Factor analysis of nonroutine task characteristics items[a,b]

Items	Factor one	Factor two
	Level of prior conceptual knowledge	Level of knowledge intensiveness
1. The know-how for technologies used in this program is well developed; the technical issues are well understood.	**0.771**	−0.219
2. The project being developed is building upon the findings from fundamental and basic research.	**0.710**	0.094
3. There are well established concepts and theories which provide a high level of predictability for the technology being developed.	**0.806**	0.050
4. A well established body of prior research exists (trade and professional journals, technical reports) to draw upon in developing this project.	**0.668**	0.223
5. Most of the discoveries or breakthroughs for this project have already been developed.	**0.610**	0.312
6. The knowledge required for the development of this project is acquired through an orderly and predictable series of controlled experiments.[c]	0.382	0.320
7. To what extent does the completion of the task require development of new procedures to solve a problem?	0.014	**0.824**
8. To what extent does trial and error play a role in arriving at the correct solutions to problems?	0.014	**0.687**
9. To what extent do you have to acquire or develop new knowledge in order to do development work?	−0.190	**0.777**
Eigen value	2.77	2.05
Variance explained	30.8	22.9

[a] $N=81$.
[b] Bold print highlights factors loadings with absolute values greater than 0.50.
[c] Item was dropped from further analysis due to loading below 0.50.

well developed and understood; the extent to which there were well established concepts and theories; the extent to which there was a build-up on findings from fundamental and basic research; and extent to which a well established body of research existed to draw upon. One item which loaded at less than 0.50 was dropped from further analysis. The second factor was represented by the following items: extent completion of the task requires the development of new procedures; extent new knowledge has to be acquired or developed; and the extent that trial and error plays a role in arriving at the correct solution to problems. We labeled this factor *level of knowledge intensiveness.* Factor scores were computed by averaging across-item scores. The Cronbach alpha for this scale was 0.67.

4.2. Analysis of variance

Univariate analyses of variance (ANOVAs) revealed significant differences between the Aim and Blitz on three out of the four knowledge development barrier factors. As shown in Table 4, the Aim project displayed significantly higher levels of: knowledge sharing and planning barriers ($F=4.56$, df$=1,41$, $p<0.05$); knowledge frame of reference barriers ($F=4.86$, df$=1,41$, $p<0.05$); and the knowledge acquisition barrier ($F=3.77$; df$=1, 41$, $p<0.05$). No significant difference was found with respect to the knowledge retention and procedural barriers.

The ANOVAs on the measures of project complexity and nonroutine task characteristics established that the Aim and Blitz projects were equivalent on

TABLE 4

Means, standard deviations, and analysis of variance of knowledge development barrier factors[a]

Factors		Aim project ($n=36$)		Blitz project ($n=7$)		F-value[b]
		Means	Standard deviations	Means	Standard deviations	
1.	Knowledge sharing and planning barriers	4.03	1.21	2.98	1.07	4.56*
2.	Knowledge frame of reference barriers	3.65	1.22	2.54	1.19	4.86*
3.	Knowledge retention and procedural barriers	3.90	1.00	3.31	1.13	1.94
4.	Knowledge acquisition barriers	5.19	1.26	4.14	1.57	3.77*

[a] $N=43$.
[b] df$=1,41$.
*$p<0.05$.

the project complexity and nonroutine dimensions. No significant differences were found either on the level of technical complexity and difficulty ($F = 1.14$, df$=1{,}41$, $p < 0.291$), level of prior conceptual knowledge ($F = 0.120$, df$=1{,}41$, $p < 0.730$), or level of knowledge intensiveness ($F = 0.783$, df$=1{,}41$, $p < 0.381$).

Based on the data collection methods as outlined in the previous sections, we turn now to the findings from the interview data.

4.3. Team learning force field analysis

Content analysis of the interview data identified eleven categories descriptive of forces that were both enabling and disabling to team learning during the product development process. Five themes were categorized as conditions which enabled or facilitated the knowledge development of the team, and six themes were identified as forces that had a diminishing or disabling effect on team learning. Interview responses from the 34 Aim and 21 Blitz subjects were sorted and tallied for each category.

As shown in Fig. 1, the findings from the content analysis of the project interview data are represented in the form of a team learning force field diagram (Lewin, 1951). The diagram reveals that the percentage of responses that made reference to the enabling conditions were dramatically and consistently higher among Blitz subjects. As illustrated in Fig. 1, forces enabling team learning included: small, informal forums; norms conducive to knowledge sharing; active engagement in inquiry; appreciation of product system interdependencies; and, participative management.

Small, informal forums and the fluid arrangements among 71.4 percent of Blitz project members were seen as facilitating their ability to develop new knowledge. Deliberations for analyzing technical data were unscheduled and emergent. Forums for discussing such topics were held informally in small groups of four to five people. Comments from several Blitz project members are illustrative: "Our interactions are close and continuous"; "Mainly meetings with the team are informal affairs"; "We see each other just about every day and so we all know what others are up against".

The interview data indicated striking differences in the degree to which knowledge sharing was a norm within the project teams. Indeed, 85.7 percent of Blitz subjects reported the norms within their team were conducive to knowledge sharing in contrast to only 9 percent of the subjects in the Aim project. The atmosphere in the Blitz project was clearly more open, as one subject stated: "There is a good exchange of perspectives among us. People aren't trying to hide things in our group." As another Blitz subject noted: "The new people are working hard and learning from each other, and not re-inventing the wheel." Moreover, the locus of expertise in the Blitz project was widely distributed. The egalitarian climate among Blitz project members was evident in that ideas and knowledge were circulated within the public domain.

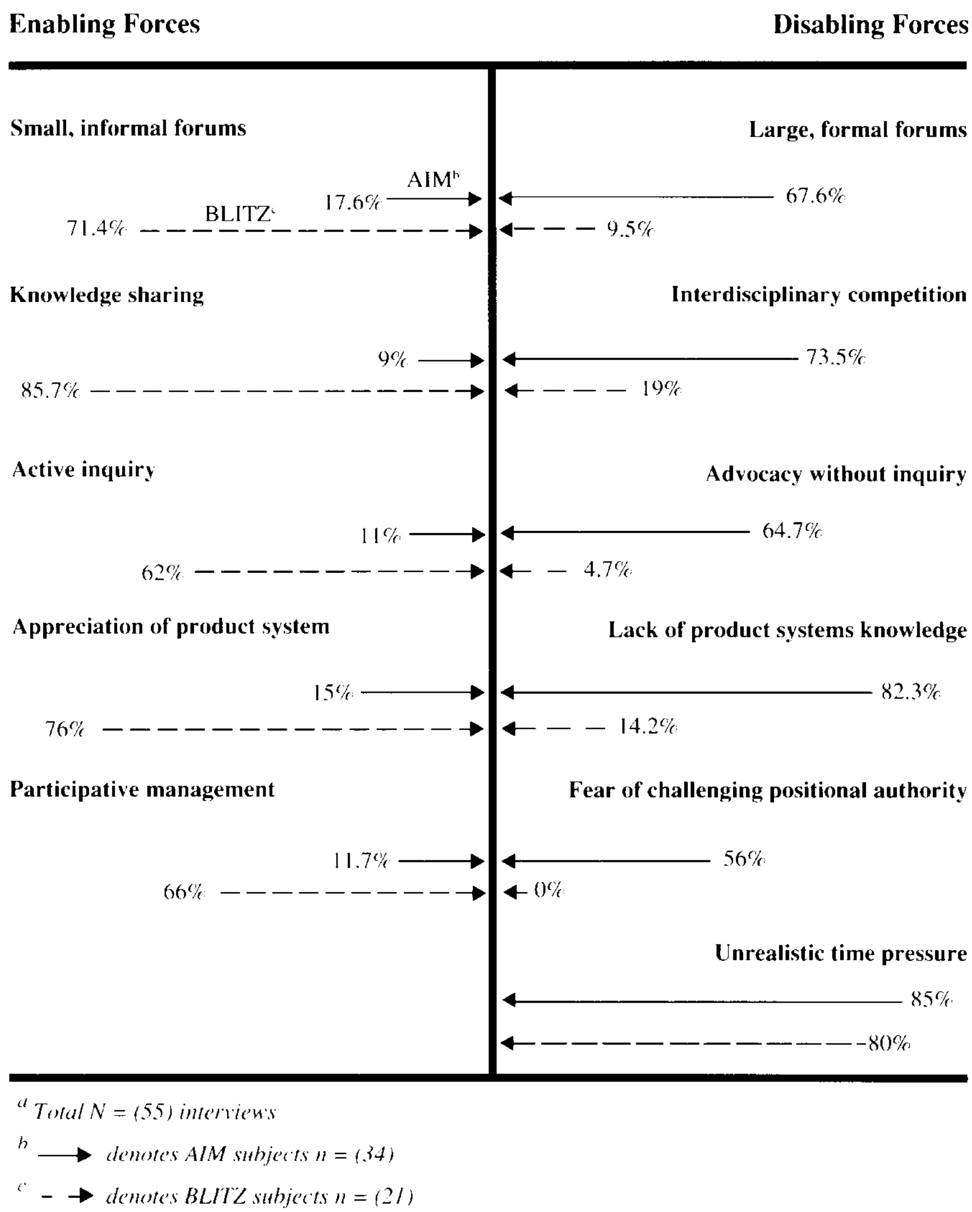

Fig. 1. Team learning force field analysis.

Sixty-two percent of Blitz subjects reported incidents in which they were engaged in active inquiry. Active inquiry within Blitz deliberations manifested as free spirited dialogue, healthy debates and open, honest discussions concerning the considerations of different technical alternatives. Prior to making a major decision to scale-up a solution, Blitz team members frequently would debate the pros and cons of the technical approach under consideration. The willingness of Blitz subjects to engage in active inquiry was unequivocally higher than their Aim counterparts. Statements like the following were expressed:

"Sometimes we get into pretty heated discussions about the merits of an approach"; "Our project manager actually invites us to state our views, even if they go against his"; "Some of us come from such different backgrounds that we don't always see eye to eye, but in the end we come out with a better solution". The fact that most of the members assigned to the Blitz project were new to the organization also explains why they were more open to spirited inquiry and debate. The Blitz project manager made this observation:

> "One factor that helped us with Blitz was new people. Other than three people, all the rest were new. They didn't have the baggage and biases. The strength of this team is the diversity; we now can recognize our differences and with a new team it is easier to do so. So the recognition of our differences has been used to extend our knowledge of the tasks."[1]

In sum, the enabling conditions conducive to active engagement in inquiry had a "variety amplifying" effect (Nonaka, 1988), which in turn facilitated a more thorough exploration and integration of divergent perspectives.

The Blitz project from the onset was highly dependent upon marketing inputs as a means for determining and adjusting product specifications. In response to the inputs from marketing, Blitz project members were constantly needing to make changes in the prototype. Evidently the interdisciplinary composition of Blitz made individual team members more appreciative and aware of the interdependent nature of the problems they were working on. In fact, 76 percent of Blitz subjects indicated the importance of paying attention to how their tasks could potentially impact the product system. Gatekeeping in the Blitz project was evidently a redundant group function rather than a specialized role invested in a single individual. Perhaps this situation is much like one subject stated: "We all take responsibility for initiating and following up on details with other groups."

As the data in Fig. 1 show, 66 percent of Blitz subjects reported that the project management was decentralized and participative. This shift in management style was a radical departure from the traditional, autocratic style which had been characteristic of the company's founder and management lineage. Reflecting on this shift, the Blitz project manager noted:

> "We have a culture that is not only top-down, but because we have a technical management, it has meant that a manager should know all the details. Now the change I see in my role is that I should know only enough details to ask the right technical questions — to give people room for influence. The message is recognizing that we shouldn't have to know the details to the degree that we sap the energy and motivation of the real problem-solvers. The Blitz organization is very fluid. The Blitz group is really making all the day-to-day technical decisions."

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[1]The fact that most members were new to Blitz and were receptive to new ideas is consistent with previous research by Katz. For further discussion on the relationship between project tenure and R&D performance, see Katz (1978) and Katz and Allen (1982).

Further, the data in Fig. 1 support the observation that participative management of the Blitz project represents a radical departure from the corporate culture. While 61 percent of Blitz subjects characterized the management of the project as participative, only 11.7 percent of the Aim subjects did so.

It is also clear from Fig. 1 that a higher percentage of responses of disabling conditions were reported by Aim subjects as compared to those in Blitz. Responses reporting disabling conditions — or forces against team learning — fell into six categories, which included: formal, large forums; severe interdisciplinary competition; excessive advocacy without inquiry; lack of product systems knowledge; fear of challenging positional authority; and unrealistic time pressures.

In the case of the Aim project, managers relied upon large bi-weekly forums as the major integrating mechanism for coordinating the activities among the different technical disciplines. Information flow between technical disciplines was usually limited to the exchange which occurred in these formal product integration forums. We were surprised to find that 30 to 40 professionals regularly attended these forums, typically lasting 3–4 hours, and covering as many diverse technical topics that could be accommodated on the agenda. These large forums were held on the fourth floor of the building where Aim project managers' offices were located — which was often referred to as the "Ivory Tower". Aim professionals also reported that they felt compelled to spend time preparing their presentations, as these meetings were usually chaired by high-ranking Aim project managers. Not surprisingly, 67.6 percent of Aim subjects reported that knowledge sharing was extremely difficult in the formal atmosphere of these large forums.

An additional force against team learning in the Aim project had to do with the fact that the allegiance of most professionals was primarily to meeting the objectives and requirements as defined by their respective technical disciplines. Laboratories assigned to the Aim project were segmented by technical discipline. Typically, disciplined-based laboratories focused on specialized topics and localized sub-problems. While laboratories were often successful in performing experiments on a bench-top scale — their local solutions — once they were scaled-up, usually caused worse problems in other segments of the product system. These structural arrangements led to severe interdisciplinary conflicts and dysfunctional forms of competition. In fact, 73.5 percent of the Aim subjects identified severe interdisciplinary competition as a major learning disability. As meetings became less interactive, knowledge sharing and data assimilation became more difficult. As one Aim subject noted:

> "One group did an experiment to identify the direction to go; we took the same data and our analysis indicated an opposite direction. The meetings took on a 'we' vs. 'they' tone as each side tried to discredit the other sides data."

It is also worth noting that the Aim project was initiated without soliciting marketing inputs or including marketing representatives in key deliberations. As the corporate project manager for Aim admitted: "We don't have a personal relationship with marketing. On the consumer side we usually say to them...here is the product, now go and sell it".

Whereas Blitz project members reported being actively engaged in inquiry, 64.7 percent of the Aim subjects described conditions that disabled constructive and incisive inquiry. Advocacy overshadowed inquiry when Aim members invested more energy in defending their personal biases and opinions — obscuring a full exploration of the data and inhibiting constructive discussions of the problem at hand. Relying almost exclusively upon their isolated know-how and personal biases, the knowledge development process was highly politicized in Aim. Aim members were well aware of this tendency. In fact, a sign on the wall in the meeting room read, "Let the data do the talking, rather than the advocates do the lobbying". For example, there was a considerable amount of controversy regarding the interpretation of Aim pilot test data. Test results of an experimental material resulted in multiple interpretations of the actual effect it was having in the product system. As one Aim scientist observed: "There was a fair amount of bias in these deliberations as people were working with mental images of their own favorite mechanisms". Another Aim scientist who participated in deliberations where pilot test data were the topic of discussions described them this way:

> "Because the goal is to show that we are fixing the problem, key parties have biases which affect decisions. There is generally information missing. We don't do a good assessment of the parameters under all conditions. Personal biases of people tend to minimize the secondary problems which could result from their favored solutions."

A high degree of task interdependence between technical disciplines and interactive technologies requires that team members have an understanding of the product system architecture. In this case that meant having access to a basic knowledge of the compatibility and interaction effects of the various materials and components used in the product. As the data in Fig. 1 show, knowledge of the product system architecture was practically non-existent in Aim; 82.3 percent of Aim subjects indicated they did not understand the product system. By comparison, only 14.2 percent of Blitz subjects identified this condition as problematic. The Director of R&D spoke at length to us about his concerns that the majority of the product system architecture know-how was inaccessible. Only several senior Aim project managers (including himself) understood or were even knowledgeable of the mechanisms within the Aim product system architecture. This knowledge was primarily intuitive and tacit; it was not codified, and therefore was inaccessible to Aim project members. As one Aim scientist put it, "...to the rest of the organization, the product system is an empirical mystery composed of 50,000 permutations of variables."

Not surprisingly, Aim project members were highly dependent upon senior managers. Comments from Aim subjects revealed that because such knowledge was not widely distributed or easily accessible, dissenting or contrary information presented by scientists could easily be discredited (and it often was) by managers who had command of the product systems knowledge base. In effect, the organizational memory of the Aim project was highly centralized. As these group dynamics were enacted in deliberations, the superior–subordinate relationships became increasingly a source of tension. As this Aim scientist laments:

> "The vice president did things by remembering from experiment to experiment, and the director does it, the project manager does it. It happens that this culture favors the keeping of oral histories. I make an observations and someone higher up will come along and say, '...but don't you remember?', and then I feel so powerless."

In comparison to the more egalitarian climate within Blitz, the relationship between Aim project managers — who had command over the knowledge base — and professionals was essentially paternalistic.

Aim subjects also revealed how perceptions of authority influenced project members' reluctance to share divergent perspectives, especially if it was "bad news". As the data in Fig. 1 show, 56 percent of Aim subjects cited instances where they refrained from offering contradictory views or challenging positional authority because of fear of retaliation and intimidation. Professionals who had the courage to occasionally "take on" the director by offering information which contradicted or challenged current technical strategies were more often than not verbally ridiculed in front of their peers. After either witnessing or being victimized by several of these incidents, most Aim members learned very quickly to censor themselves. For example, statements from several Aim members characterize the climate in key Aim deliberations: "There is no doubt that the director is a genius, in fact, he has a photographic memory. I've seen him tear people to shreds", "Hey, I'm not going to ruin my career by telling the director what he doesn't want to hear".And an Aim manager conceded: "We need to avoid this 'Stalinist approach' to developing technology". On a milder note, this Aim scientist noted how discussions of technical alternatives were squelched in deliberations:

> "Historically there has been lack of support for deviant opinions. There is an environment that wants to pick a leading candidate because there is a political need to do so. After this there is a tendency to close the debate. This is why we scaled-up the current material. Even though it is a problem, it somehow has become a sacred cow. We have the data that says it screws up the prototype, but we still continue to use it. If you discuss this you are cast as a heretic or negative person."

Some Aim members reported feeling like their technical competence was always on the line, and, as a result, were overly cautious in publicizing their thinking and ideas in front of management. In contrast, none of the Blitz subjects that were interviewed reported incidents where they felt hesitant, reluctant, or fearful of challenging positional authority.

Interestingly, the percentage of responses indicating the presence of unrealistic time pressure as a disabling condition were not appreciably different between projects. Subjects in both projects lamented about how there was never enough time to examine all the data. However, Blitz subjects were consulted from the onset of the project in regards to scheduling. Aim scientists, on the other hand, were excluded from deliberations where initial goals and schedules were set by management.

Do these enabling and disabling learning conditions relate to project outcomes? The answer is a definitive yes. While both projects were initiated at the same time, Aim project members still have not been able to release the product into the marketplace. In contrast, the Blitz project was completed in three years — twice as fast as the mean time in development for the majority of projects in the division.

5. Discussion and research implications

This study examined two research projects in a major U.S. corporation to answer the question, "what factors associated with the management of deliberations enable or obstruct knowledge development in new product development teams?" Four factors were identified from an analysis of survey data which accounted for a significant amount of variance in the perceptions of technical professionals regarding knowledge development: (1) knowledge sharing and planning; (2) knowledge frame of reference; (3) knowledge acquisition; and (4) knowledge handling procedures[2]. The first three of these factors differentiated significantly the experiences of members of the two project teams studied. In addition, interviews with project members were content analyzed to discover explanations for apparent differences between the projects. Forces enabling team learning on the more successful project included small informal forums versus large, formal forums; knowledge sharing versus interdisciplinary competition; active inquiry versus advocacy without inquiry; appreciation of the product system versus a lack of product systems knowledge; and participative management versus a fear of challenging positional authority. Another knowledge barrier, unrealistic time pressure, was felt equally by the more successful and less successful project.

While the generalizability of our research is limited by the fact that we have addressed only two projects in the same corporation, the data do seem to point to some interesting conclusions. First, it is apparent that Tornatsky et al. (1983) were correct in their assertion that there is much more to know about infor-

[2]For further discussion on the role of frames of reference in knowledge development, see Huber (1991), Shrivastava and Mitroff (1983), and Shrivastava and Schneider (1984).

mation processing in RD&E organizations than we could ever learn from a simple sociometric analysis of information exchange relationships. The acquisition, sharing and utilization of knowledge in RD&E organizations occur in deliberations with distinctly different foci; to understand the rate and quality of learning in RD&E organizations, we need to look much more closely at these deliberations in order to understand the human and organizational factors that affect each type of deliberation. To optimize knowledge acquisition, for example, may require that different participants come together in different forums, with different levels of influence and supported by different resources and procedural arrangements than is the case for other types of deliberations. Thus, "deliberation specialization" may be a much more powerful organizing mode than functional specialization from a learning standpoint. In the deliberation specialization mode, participants would be allied with deliberations in which their knowledge and skills were most useful; their influence and role in the deliberation would reflect the nature of the contribution their expertise allowed them to make. Reward systems might also be aligned with deliberation activities and outcomes, so that RD&E professionals would benefit from planning and conducting successful deliberations. The emphasis would be on knowledge sharing rather than upon interdisciplinary competition, and the role of the hierarchy in making decisions would be described by the deliberation plan, which in turn is based upon the alignment of knowledge with influence.

"Deliberation specialization" would help to clarify needed shifts in project leadership and personnel as projects move through phases of activity. Rather than "throwing the work over the wall", project management based on deliberation specialization would connect key participants to projects over time with clearly defined roles and responsibilities that would prevent functional representatives from "dropping the ball". More importantly, deliberation specialization would make the distinct nature of deliberations and knowledge resources required much more explicit. Theoretically, this would prevent a small group of influential professionals or managers from believing that they alone possessed the knowledge to make all decisions regarding the advancement of projects. Even without reorganizing, more explicit attention to the unique nature of different deliberations required in RD&E projects should produce insights into current knowledge barriers and lost knowledge enhancing opportunities. We fully support Tornatsky et al.'s (1983) call for more detailed research into the nature of information exchange relationships during different phases of the RD&E process.

A second learning from this research is that even within the same corporation, projects of a vastly different sociotechnical culture can and do exist. Furthermore, while our data cannot support this finding unequivocally, it seems that there is strong evidence in the comparison of the two projects to indicate that the culture of a project may affect project success. Based on what we observed in these two projects, we conclude that technically complex and highly nonroutine projects are more likely to succeed in a participative learning system[3] (Shrivastava, 1983). A project manager would do well to involve professionals in the design and creation of a participative learning system by organizing people into small, informal teams; by ensuring knowledge sharing across disciplines; by promoting active inquiry as a means of informing decisions; by exposing more people to the "big picture" of how the overall product system functions; by utilizing a participative approach to decision making; by encouraging thoughtful planning of deliberations; by helping participants develop a common language; by making certain all relevant parties are included in technical discussions; by helping participants discover common values and frames of reference; by providing adequate time for learning to occur; and by making certain that people are aware of critical knowledge that is missing and how to get it if possible.

While many of these suggestions appear to be based upon common sense, it was very clear in our analysis of the two projects that different organizational structures, participant characteristics and leadership styles existed in the Aim and Blitz projects, and that the resulting absence of the factors mentioned above made it difficult for participants in the Aim project to develop and share the knowledge needed to achieve success quickly and efficiently. It appears that the concept of "organizational choice" (Trist et al., 1963), which specifies that many social and technical arrangements are possible and that some are better than others, is as relevant to the nonroutine work of RD&E organizations as it is to more routine work in manufacturing organizations.

More generally, we would offer the following guidelines for maximizing learning in RD&E organizations:

The existence of a conceptual knowledge base facilitates both learning and implementation. To the extent that agreement exists on the underlying theory of cause and effect relationships associated with technology under development, project success is likely to increase (Foster, 1986; Souder, 1987). Organizations that develop products through empirical methods (a series of experiments) without understanding the theory behind their work actually create barriers to sharing, interpreting and applying knowledge. Relatively few people can understand and utilize data from thousands of experiments, let alone anticipate the difficulties that are likely to be encountered in undertaking the development of a new product.

Unrealistic time pressures interfere with communication, learning, and the development of a conceptual knowledge base. The perception of unrealistic time pressure can often be circumvented by including project members in goal-setting and scheduling deliberations. Deadlines which are negotiated rather than

[3]Another illustrative example of the participative learning system is described in a case study of Canon, Inc. (Nonaka and Kenney, 1991).

dictated can be motivating (Latham and Locke, 1975). Adequate time is necessary to hold deliberations, formulate theories and document learnings. Many organizations however run their projects on schedules that are overly tight, driving out the time needed to allow the organization to learn. While the pace of activity under time pressure may increase, research suggests that time pressure can be motivating only up to a point (Andrews and Farris, 1972; Kelly and McGrath, 1985). Rather than treating each project as if it were the organization's last, each project should be looked at as the first of many to follow.

Learning is a balancing act that requires psychological safety. Using an example provided by Bateson (1972), the behavioral features of effective learning systems may be compared to an acrobat on a high wire. As Bateson (1979, p. 498) states:

> "During the period when the acrobat is learning to move his arms in an appropriate way, it is necessary to have a safety net under him, i.e., precisely to give him the freedom to fall off the wire. Freedom and flexibility in regard to the most basic variables may be necessary during the process of learning..."

Following Ashby's law of requisite variety, effective learning systems are those in which knowledge is widely distributed. Participative learning systems exhibit more requisite variety, resiliency and flexibility; such systems are more likely to learn from their mistakes than systems which rely primarily on the hierarchy, or worse, those that operate as "one man" learning institutions (Shrivastava, 1983). Thus, the degrees of freedom in participative learning systems are higher, allowing participants to experiment with new methods and challenge existing paradigms.

The knowledge base must be integrated. While learning is to be valued highly, it is the application of knowledge that is the end goal of RD&E organizations. In the past, specialized professionals have viewed the creation of a "piece" of knowledge as their responsibility, *not* seeing that their learning is integrated into the final product. In organizations that align knowledge with influence and operate in a more participative fashion, professionals must take responsibility for the final outcomes achieved by the coordinated work of all involved in the RD&E effort. To accomplish this, it is important that deliberations are planned and held to include all relevant technical stakeholders and that the responsibility for decision making is shared with those who understand fully the implications of the technical decisions being made.

A final learning from the study not to be underemphasized is that nonroutine work is analyzable and therefore open to research, redesign and management. While Quinn (1985), Nonaka (1988) and others who maintain that new product development requires a balance between order and disorder are correct, it seems clear from our results that much of the "disorder" currently experienced by product development teams is unnecessary. By analyzing knowledge requirements, knowledge acquisition processes and knowledge sharing procedures, deliberations can be planned that eliminate *unnecessary* disorder in the product development process. While creativity, discovery, intuition, and luck will continue to play a large part in successful product development efforts, the portion of the work which is made nonroutine by virtue of poor organizational arrangements and managerial processes can be reduced. Social arrangements influence directly that difficulty of organizational learning.

In the future, research should be conducted that examines the effects of different organizational leadership and deliberation arrangements on organizational learning across a wider array of organizational settings. Although the two projects reported here varied substantially, they represent only a small portion of the spectrum of project arrangements currently in use. Moreover, the projects studied did not differ significantly on their degree of technical difficulty. We would hypothesize that different learning processes and organizational arrangements would be appropriate in high- versus low-complexity environments.

We would also be interested in experimental, longitudinal studies that examine the effects of different deliberation arrangements on project outcomes. The current research is limited by the fact that our data sources were largely retrospective and open to common methods variance. Laboratory experiments that examine the effects of manipulating leadership styles, membership or information richness in deliberations would also be extremely innovative.

Overall, more research should be done which examines the actual "work" performed in RD&E organizations, with attention given to examining and improving methods and procedures. Although knowledge work will always involve uncertainty, research in this arena may help us to better understand and facilitate organizational learning.

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References

Andrews, F. and Farris, G., 1972. Time pressure and performance of scientists and engineers: A five year panel study. *Organ. Behav. Hum. Perform.*, 24: 202–227.

Allen, T., 1986. Organizational structure, information technology, and R&D productivity. *IEEE Trans. Eng. Manage.*, 33(4): 212–220.

Allen, T. and Hauptman, O., 1987. The influence of communication technologies on organizational structure: A conceptual model for future research. *Commun. Res.*, 14(5): 575-587.

Allen, T., Tushman, M. and Lee, D., 1979. Technology transfer as a function of position in the spectrum from research through development to technical services. *Acad. Manage. J.*, 22(4): 694-708.

Bateson, G., 1972. *Steps to an Ecology of Mind.* Ballantine, New York, NY.

Brown, J., 1991. Research that reinvents the corporation. *Harv. Bus. Rev.*, (January-February): 102-111.

Brown, J. and Duguid, P., 1991. Organizational learning and communities-of-practice: Towards a unified view of working, learning and innovation. *Org. Sci.*, 2(1): 40-57.

Burns, T. and Stalker, G., 1961. *The Management of Innovation.* Tavistock Publications, London.

Carlsson, B., Keane, P. and Martin, J., 1976. R&D organizations as learning systems. *Sloan Manage. Rev.*, (Spring): 1-15.

Cummings, T. and Mohrman, S., 1985. Organization design for the future: A collaborative research approach. In: E. Lawler, A. Mohrman, S. Mohrman, G. Ledford and T. Cummings (Eds.), *Doing Research Useful for Theory and Practice.* Jossey-Bass, San Francisco, CA.

Daft, R. and Lengel, R., 1986. Organizational information requirements, media richness and structural design. *Manage. Sci.*, 32 (5): 554-571.

Daft, R. and Macintosh, N., 1981. A tentative exploration into amount and equivocality of information processing in organization work-units. *Admin. Sci. Q.*, 26: 207-224.

Davis, P., and Wilkof, M., 1988. Scientific and technical information transfer for high technology: Keeping in the figure in its ground. *Res. Dev. Manage.*, 18(1): 45-55.

Duncan, R. and Weiss, A., 1979. Organizational learning: Implications for organizational design. In: L.L. Cummings and B. Staw (Eds.), *Research in Organizational Behavior*, Vol. 1. JAI Press, Greenwich, CT.

Evered, R. and Louis, R., 1981. Alternative perspectives in the organization sciences: Inquiry from the inside and inquiry from the outside. *Acad. Manage. Rev.*, 6: 385-395.

Fiol, M. and Lyles, M., 1985. Organizational learning. *Acad. Manage. Rev.*, 32: 543-576.

Foster, R., 1986. *The Attacker's Advantage.* Summit Books, New York, NY.

Galbraith, J., 1977. *Organizational Design.* Addison-Wesley, Reading, MA.

Hair, J., Anderson, R., Tatham, R. and Grablowsky, B., 1984. *Multivariate Data Analysis.* Macmillan, New York, NY.

Hedberg, B., 1981. How organizations learn and unlearn. In: P. Nystrom and W. Starbuck (Eds.), *Handbook of Organization Design*, Vol. 1. Oxford University Press, New York, NY.

Huber, G., 1991. Organizational learning: The contributing processes and the literatures. *Org. Sci.*, 2(1): 88-115.

Imai, K., Nonaka, I. and Takeuchi, H., 1985. Managing the new product development process: How Japanese companies learn and unlearn. In: K. Clark, R. Hayes and C. Lorenz (Eds.), *The Uneasy Alliance.* Harvard Business School, Boston, MA.

Jelinek, M., 1979. *Institutionalizing Innovation: A Study of Organizational Learning Systems.* Praeger, New York, NY.

Kanter, R.M., 1988. When a thousand flowers bloom: Structural, collective, and social conditions for innovation in organizations. In: L.L. Cummings and B. Staw (Eds.), *Research in Organizational Behavior*, Vol. 10. JAI Press, Greenwich, CT.

Katz, R., 1978. The influence of job longevity on employee reactions to task characteristics. *Hum. Relat.*, 31: 703-725.

Katz, R. and Allen, T., 1982. Investigating the Not Invented Here (NIH) syndrome: A look at the performance, tenure, and communication patterns of 50 R&D project groups. *Res. Dev. Manage.*, 12(1): 7-19.

Kelly, J. and McGrath, J., 1985. Effects of time limits and task types on task performance and interaction of four person groups. *J. Personality Soc. Psychol.*, 49: 395-407.

Latham, G. and Locke, E., 1975. Increasing productivity with decreasing time limits: A field replication of Parkinson's law. *J. Appl. Psychol.*, 60: 524-526.
Lawrence, P. and Lorsch, J., 1967. *Organization and Environment: Managing Differentiation and Integration*. Harvard Business School, Boston, MA.
Levitt, B. and March, J., 1988. Organizational learning. *Annu. Rev. Sociol.*, 14: 319-340.
Lewin, K., 1951. *Field Theory in Social Science*. Harper and Row, New York, NY.
Lundberg, C., 1989. On organizational learning: Implications and opportunities for expanding organization development. In: W. Pasmore and R. Woodman (Eds.), *Research in Organizational Change and Development*, Vol. 3. JAI Press, Greenwich, CT.
Meyers, P., 1990. Non-linear learning in large technological firms: Period four implies chaos. *Res. Policy*, 19: 97-115.
Meyers, P. and Wilemon, D., 1989. Learning in new product development teams. *J. Prod. Innov. Manage.*, 6 79-88.
Morgan, G. and Ramirez, R., 1983. Action learning: A holographic metaphor for guiding social change. *Hum. Relat.*, 37(1): 1-28.
Nonaka, I., 1988. Creating organizational order out of chaos: Self-renewal in Japanese firms. *Calif. Manage. Rev.*, 30: 57-73.
Nonaka, I. and Johansson, J., 1985. Japanese management: What about the 'hard' skills? *Acad. Manage. Rev.*, 10(2): 181-191.
Nonaka, I. and Kenney, M., 1991. Towards a new theory of innovation management: A case study comparing Canon, Inc. and Apple Computer, Inc. *J. Eng. Technol. Manage.*, 8: 67-83.
Nunnally, J., 1978. *Psychometric Theory*. McGraw Hill, New York, NY, 2nd edn.
Pasmore, W., 1988. *Designing Effective Organizations: The Sociotechnical Systems Perspective*. Wiley, New York, NY.
Pava, C., 1983. *Managing New Office Technology*. Free Press, New York, NY.
Pava, C., 1986. Redesigning sociotechnical systems design: Concepts and methods for the 1990s. *J. Appl. Behav. Sci.*, 22(3): 201-221.
Perrow, C., 1967. A framework for the comparative analysis of organizations. *Am. Sociol. Rev.*, 32: 194-208.
Purser, R. and Pasmore, W., 1992. Organizing for learning. In: R. Woodman and W. Pasmore (Eds.), *Research in Organizational Change and Development*, Vol. 6. JAI Press, Greenwich, CT.
Quinn, J., 1985. Managing innovation: Controlled chaos. *Harv. Bus. Rev.*, (May-June): 76-83.
Shrivastava, P., 1983. A typology of organizational learning systems. *J. Manage. Stud.*, 20(1): 9-25.
Shrivastava, P. and Mitroff, I., 1983. Frames of reference managers use: A study in applied sociology of knowledge. In: R. lamb (Ed.), *Advances in Strategic Management*. JAI Press, Greenwich, CT.
Shrivastava, P. and Schneider, S., 1984. Organizational frames of reference. *Hum. Relat.*, 37: 795-809.
Souder, W., 1987. *Managing New Product Innovations*. D.C. Heath and Company, Lexington, MA.
Stata, R., 1989. Organizational learning: The key to management innovation. *Sloan Manage. Rev.*, 30(1): 63-73.
Susman, G., 1983. Action research: A socio-technical perspective. In: G. Morgan (Ed.), *Beyond Method: Strategies for Social Research*. Sage Publications, Beverly Hills, CA.
Thompson, J., 1967. *Organizations in Action*. McGraw-Hill, New York, NY.
Tornatsky, L., Eveland, J., Hetzner, W., Johnson, E., Roitman, D. and Schneider, J., 1983. *The Process of Technological Innovation: Reviewing the Literature*. National Science Foundation, Washington, D.C.

Trist, E., 1983. Afterword. In: C. Pava, *Managing New Office Technology*. Free Press, New York, NY.
Trist, E., Higgin, G., Murray, H. and Pollock, A., 1963. *Organizational Choice*. Tavistock Publications, London, UK.
Tushman, M., 1979. Work characteristics and sub-unit communication structure. *Admin. Sci. Q.*, 22: 82-98.
Tushman, M. and Nadler, D., 1980. Communications and technical roles in R&D laboratories: An information processing approach. In: B. Dean and J. Goldhar (Eds.), *Management Research Innovation*. North-Holland, Amsterdam, The Netherlands.
Van de Ven, A. and Delbecq, A., 1974. A task contingent model of work-unit structure. *Admin. Sci. Q.*, 19: 183-197.
Weick, K., 1979. *The Social Psychology of Organizing*. Random House, New York, NY.
Weick, K., 1991. The nontraditional quality of organizational learning. *Organ. Sci.*, 2(1): 116-124.
Weisbord, M., 1987. *Productive Workplaces*. Jossey-Bass, San Francisco, CA.
Withey, M., Draft, R. and Cooper, W., 1983. Measures of Perrow's work unit technology: An empirical assessment and a new scale. *Acad. Manage. J.*, 26(1): 45-63.
Whyte, W., 1991. *Participatory Action Research*. Sage, Newbury Park, CA.

Appendix

Knowledge development barriers

This section contains statements which describe a number of different types of problems which you may have encountered in deliberations. We are referring to such problems as knowledge development barriers. Please identify the extent to which any of the barriers below negatively impact deliberations and the performance of your research project.

To what extent do any of the barriers listed below impact the deliberations in your research project?

1	2	3	4	5	6	7
To no extent; this barrier does not impact the project		To some extent; this barrier has a moderately negative impact			To a great extent; this barrier has a significantly negative impact	

__(a) *Lack of knowledge*: Not all of the information and knowledge required for doing the task or making decisions is available when it is needed.

__(b) *Failure to utilize knowledge*: The information and knowledge for doing the task and making decisions is available, but it is usually ignored or used incorrectly.

__(c) *Lack of knowledge-sharing*: Because of conflicts or mistrust between people or groups, important knowledge and information is withheld.

__(d) *Lack of cooperation*: Because of the lack of cooperation between various individuals, work performance and decision-making is less than optimum.

__(e) *Language barriers*: Different individuals or groups fail to assimilate critical information because of specialized language barriers.

__(f) *Missing parties*: People who have relevant information are missing from key discussions.

__(g) *Wrong parties*: Some people are involved in discussions or tasks which should not be.

__(h) *Lack of planning*: Important tasks and discussions are impaired because of a lack of preparation and planning.

__(i) *Unrealistic timeframes*: Commitments to time schedules are made with inadequate input from other parties.

__(j) *Unclear procedures*: Procedures for important tasks are either unclear, ambiguous, or non-existent.

__(k) *Lack of internal consulting*: Important information from other areas within the division is not taken into account before major technical decisions are made.

__(l) *Lack of external consulting*: Important information from other divisions and the environment is not taken into account before major technical decisions are made.

__(m) *Overstructured forums*: The rules and climate in key forums are too formal; relevant issues or proposals are not considered.

__(n) *Understructured forums*: The rules and climate in key forums are too informal; irrelevant issues and proposals are considered.

__(o) *Diffused responsibilities*: Too many people have responsibility for the same task; everyone assumes that someone else is following through on important items.

__(p) *Lack of technical documentation*: Relevant past work is inaccessible because of lack of documentation. There is much repetition of past experiments.

__(q) *Divergent values*: The values and orientation between various individuals or groups is too divergent; people are working at cross purposes with each other.