Facilitating Interorganizational Learning with Information Technology

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ABSTRACT: Increasingly, organizations collaborate to complement their core competencies. New product development, for example, is often a collaborative process, with customers and suppliers contributing complementary knowledge and skills. This study uses grounded theory to determine how and why information technology facilitates interorganizational learning. Semi-structured interviews in the disk drive industry were coded to develop a conceptual model. An important finding is that organizations collaborate closely through virtual integration. They need interorganizational learning to help them cope with the complexity of new products and the capital intensity in the disk drive industry. However, effective interorganizational collaboration needs trust. The main contribution of the model is in explaining the role of information technology in lower and higher levels of interorganizational learning, cognitive and affective trust, and virtual and humanistic interorganizational collaboration.

KEY WORDS AND PHRASES: collaboration, interorganizational learning, new product development, tacit knowledge, trust, virtual integration.

CLOSER TIES AMONG COMPLEMENTARY BUSINESSES have put pressure on collaborative trade partners to extend beyond traditional, arms-length contractual and transactional relationships. Businesses are extending internal processes and strategies vertically and virtually to reduce design-to-deliver cycle times and leverage channel effectiveness. But while there is a growing reliance upon interorganizational learning (IOL) to manage this organizational nexus, the role of information technology (IT) remains

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unclear. This paper inductively generates a theory and model for IT facilitation of IOL and assesses the strengths and limitations of IT in this role. To do this I analyze IOL strategies, trust relationships, the environmental, organizational, and IT contexts and the virtual integration phenomenon. The analysis provides contextual richness on the use of IT in the disk drive industry, and among its players.

IT facilitates interorganizational processes in several industries. For example, EDI enables quicker response in the textile and retail industries [14], and "electronic partnerships" in the automobile industry [7]. The Internet and supply chain management software offer advanced planning and scheduling solutions for interenterprise collaboration in manufacturing industries [10]. Another type of software, processware, promises real-time links between enterprise systems. This is an improvement over batch-oriented EDI—orders originating in a customer's system immediately trigger an update of inventory [79].

IT also improves coordination between firms [1, 44], while lowering associated risks [12]. As IT use increases and improves coordination, transaction cost economic theory [80] predicts market forces will increase because of lower coordination costs. Instead a hybrid organizational form has eventuated from a "move to the middle," a situation midway between hierarchy and market [12]. Such networked organizations [29, 49, 60, 66, 74], also called value-added partnerships [30], form "virtual" integrated entities [14, 48]. This virtual integration relies on electronic networks that enable faster information distribution and communication beyond organizational boundaries [54].

The hybrid organizational form characterizes a trend toward fewer yet closer relationships between firms and their suppliers. The result is improved quality, responsiveness, and innovation [4, 26]. IT provides the means to monitor suppliers, model new products, and engage in rapid communication in the extended enterprise. This facilitates IOL during new product development [14], which is "the core process for creating new organizational knowledge" [57]. For example, suppliers and customers engage in IOL and collaborate in product design by exchanging engineering knowledge and monitoring product development performance [14].

IOL results from the convergence of two trends. The first is the "virtual" organizational form [14,48] where barriers between organizations are made more permeable due to the influence of IT. For example, IT revolutionizes communication between firms by establishing more linkages based on contextual value-laden shared knowledge. The second trend is the growing recognition of the importance of knowledge and learning for networked organizations.

As the economy shifts to knowledge work, firms attempt to retain knowledge to avoid repeating mistakes or "reinventing the wheel." Moreover, firms are focusing on managing and creating knowledge for competitive advantage [2, 17,27, 38,42]. Collaboration at the interorganizational level usually enhances organizational learning [15, 20, 22, 55, 60]. Interorganizational collaboration catalyzes the learning process through the introduction of a wide diversity of knowledge [15]. Organizations collaborate with customers, suppliers, and competitors forming new networks of learning [57, 60]. Such knowledge links enable organizations to access and internalize the

skills and capabilities of their partner [3,22]. This enables "the extended enterprise to create new knowledge, disseminate it throughout the value chain, and embody it in joint products, services, and systems" [57, p. viii].

Techniques for learning from partners include benchmarking performance and visiting their sites [17, 38]. "Grafting" is a mechanism to quickly acquire new knowledge by learning from the experience of people external to their firm [27]. However, prior experience affects the organization's absorptive capacity and how receptive it is to new knowledge [13, 22]. How quickly the knowledge diffuses depends on an organization's ability for imitation, and its ecology of learning [42], where customers, suppliers, and competitors are potential sources of ideas, from articulation and observation [17].

This research uses grounded theory to explain how and why IT facilitates IOL. Electronic links facilitate both lower and higher levels of learning [2]. At the lower level, electronic adaptive learning systems adjust to stimuli and provide fast feedback to promote greater efficiency using explicit knowledge [41]. For example, in the textile, automobile, and insurance industries, their use of EDI and the Internet for electronic business shows how IT potentially optimizes their supply chain and reduces inventory bottlenecks [7].

At the higher level, interorganizational collaboration also catalyzes the learning process by stimulating reconsideration of current practices [15]. This challenges assumptions and is more innovative than lower-level learning [2], Innovation requires experimentation, and learning from experience to create knowledge that is initially unstructured and tacit [55]. Tacit knowledge encompasses perspectives, know-how, expertise, and context-specific skills. Tacit knowledge is difficult to articulate, communicate, formalize, and encode [22, 55, 72, 77, 81]. A high level of social interaction is necessary to surface assumptions with double-loop learning and transform this tacit organizational knowledge into explicit knowledge [2, 55].

Although IT is ideal for codifying explicit knowledge, a transaction information system, for example, is inadequate for encoding tacit knowledge [81], since it does not capture context or allow dialogue. E-mail, groupware, intranets, videoconferencing, or electronic document-based systems are better for conveying tacit knowledge through dialogue and interaction.

The role for IT in IOL involves generating both explicit and tacit knowledge in virtual value chains, which electronically connect organizations from the producers of raw materials to the end consumer. Organizations collaborating in these virtual value chains find that trust is a significant issue, since long-term meaningful exchanges of strategic and confidential information and knowledge are necessary.

Lack of Trust—A Barrier to IT Facilitation of Interorganizational Learning

Despite the potential of IT to create virtual value chains [63], certain problems persist. For example, there are cases of resistance to the adoption of EDI [24], and

concerns about the security of the Internet. However, the most significant barrier to virtual relationships and learning in collaborations is lack of trust [14, 15, 43]. Mutual trust among organizations is essential to IOL.

Mutual trust is defined as "the expectation shared by [participants] that they will meet their commitments to one another" [51, p. 413]. Collaboration depends on high levels of mutual trust to encourage the continuation and growth of successful relationships [3,15, 22, 24, 34]. With mutual trust, partners will reciprocate openness and sharing of information and knowledge over time [24, 51, 68], and be less concerned with how much knowledge "leaks out" [22]. A receptive, trusting, and supportive environment encourages risk taking and experimentation [17, 69]. Trust is necessary for organizations to feel free to learn from failure [68]. This is important because insights from failure are often instrumental in achieving subsequent success.

Trust is promoted by mutual benefits [15], and is vital for organizational learning and for change initiatives [68], such as process change and reengineering [65]. For example, when General Motors looked to technology to speed up change, but at the same time neglected trust and human collaboration, its investment of billions of dollars was ineffective [68].

A lack of trust is a barrier to effective collaboration [61]. Mistrust is more likely to occur at early stages in relationships—when stereotypes affect first impressions—than later when people come to know one another [31]. A lack of trust may increase the risk to partners because knowledge-intensive activities are not easily contractible [4]. Without a contract, partners are vulnerable. Nevertheless, the risk to the supplier is ameliorated by the knowledge that the buyer has few alternative suppliers and thus reduced bargaining power. This motivates suppliers to make customer-specific investments [4]. From a buyer's perspective, monitoring [21] suppliers with IT controls bargaining power and risk. While supplier-specific investments would increase the costs of switching to alternative suppliers, investments in IT have the advantage of not being specific to the relationship [12].

Trust is classified either as rational cognition-based or social affect-based [46, 75]. Previous studies propose that trust develops slowly, beginning with cognitive trust and advancing to affective trust. Trust is more likely to develop when there are prospects for a long-term relationship [46, 75]. Cognition-based trust is a rational view of trust and encompasses competence, ability, responsibility, integrity, credibility, reliability, and dependability [46, 50, 75]. It is associated with an organization's track record. In contrast, affect-based trust is the social view of trust and has a more emotional connotation [46]. It encompasses care, concern, benevolence, altruism, a sense of personal obligation, commitment, mutual respect, openness, a capacity for listening and understanding, and a belief that sentiments are reciprocated [3, 24, 45, 46, 50].

Monitoring can be effective for cognitive trust, tracking competence, reliability [50], and credibility [3]. However, monitoring does not induce affective trust as effectively as other management practices. Instead, a common implicit perspective from shared information and experiences and joint knowledge creation [54, 55] (preferably face-to-face), reciprocity in a partnership [8, 28,76], and trading personnel with the partner [3, 22, 24, 34] build affective trust.

In summary, trust appears essential for effective collaboration. The next section provides examples of documented collaboration and trust in the disk drive industry.

Collaboration in the disk drive industry

The disk drive industry is paradoxical. Despite the sophistication and complexity of its products, disk drives are commodities and competing products are substitutable because of standardized hardware "plug-and-play" features. Moreover, new disk drive products with greater storage capacity are continuously introduced to meet the demands of the marketplace [11]. Disk drive manufacturing and product development require robotics and expensive high-precision equipment, especially for the disk and head components. Thus, driven by the complexity of new products, shrinking time to market, and capital intensity, disk drive industry firms frequently collaborate to improve access to complementary capabilities.

Individual firms have capability gaps when strategically important technical expertise is unavailable or inadequate internally. They remedy this problem by partnering and focusing in their specific areas of expertise [39,40]. Strategic partnering reduces capital investment and the need for specialized skills. For example, this may contribute to a faster "ramping up" of a new design, with fewer manufacturing problems. Learning from customers and suppliers is essential to design innovative, high-quality drives, which satisfy computer firms' specifications. In this way, IOL forms the basis for new product development in the disk drive industry.

An example is the collaboration between the disk drive companies Quantum and MKE. Quantum has strong capabilities in design and marketing, and close OEM (original equipment manufacturing) relationships. MKE has complementary strengths in electromechanical high-volume, high-quality manufacturing. Together, Quantum and MKE bring quality products to market quickly and efficiently. Their exchange of knowledge on design and production improves the manufacturability of designs [36, 40]. Nevertheless, such IOL demands effort and persistence to build trust and overcome potential barriers to learning from national cultural differences and geographic distance [40,41]. Communication of even explicit information is difficult in a global manufacturing environment with language and cultural barriers.

Another well-documented collaboration in the disk drive industry was between Conner Peripherals and Compaq computers in the late 1980s. Working closely together, both firms enjoyed remarkable growth rates. Compaq has stated that "by far the biggest advantage of the relationship is our early access to the product and our influence over its development" [35].

Most of the disk drive industry is headquartered in Silicon Valley. Silicon Valley firms have a distinctive culture and moral commitments that are not typical of business relationships. They exchange sensitive information on business plans, sales forecasts, and costs, and establish long-term personal relationships with suppliers [15, 67]. Trust is readily established among engineering-driven organizations. This is both from the common professional bond and the community of practice [77], encouraging engineers often to share their know-how freely across organizations.

Interviews with executives in the disk drive industry reveal a strong dependence on IT. Limitations to IT facilitation of IOL have been ignored by the "technotopian" perspective [5,53]. This perspective assumes technology has a positive impact. While the organizational economic perspective explains the outcomes from the impact of IT and other forces on organizational forms, this study also attempts to look at the process itself to gain a deeper understanding of how IT facilitates interorganizational learning. The following section introduces a conceptual model and overviews the relationships among IT, IOL, collaboration, and trust.

Conceptual Model—Facilitating IOL with IT

IT FACILITATION OF IOL USES FOUR DISTINCT yet interrelated mechanisms, represented in a conceptual model (see Figure 1). The first and second mechanisms use direct IT facilitation of lower-level (arrow 1) and higher-level (arrow 2b) IOL. The third and fourth mechanisms use indirect IT facilitation of IOL involving tacit knowledge gained through trust and collaboration. Facilitation of IOL with collaborative IT is shown on the model as two steps: first collaboration (arrow 3), and then IOL (arrow 2a). Finally, monitoring and tracking suppliers generates potential reliability data that builds cognitive trust (arrow 6), then collaboration (arrow 5) and IOL (arrow 2a). The four mechanisms and the paths that relate them are represented in the integrated conceptual model.

The following section addresses research methodology and explains the rationale for using grounded theory, a form of qualitative analysis. When presenting the research results, I use grounded theory [73] to organize the analysis of the interview data. This is followed by a discussion of the grounded theory results combined with previous theory on interorganizational collaboration, trust, and learning, culminating in a conceptual model. Finally, the last section discusses the conclusion, implications for management, implications for research, limitations of the study, and proposed extensions of the research.

Research Methodology

QUALITATIVE RESEARCH METHODOLOGY—specifically, grounded theory—has reported strengths for IT research [6, 16, 37, 48, 58, 73, 78]. This methodology is appropriate for the four objectives of this study. The first is to research IOL, an area that has had few previous studies [6, 78]. The second is to explain how and why [6, 37, 48, 58] IT facilitates interorganizational learning. The third objective is to provide contextual richness [58] on the disk drive industry, its players, organizational forms, and use of IT, as well as perceptions of executives. Finally, the focus is to inductively generate a theory [6, 58, 73] for IT facilitation of interorganizational learning. Previous grounded study research has, for example, compared adoption of CASE tools in two organizations [58], and studied collaboration in a semiconductor industry consortium [8].

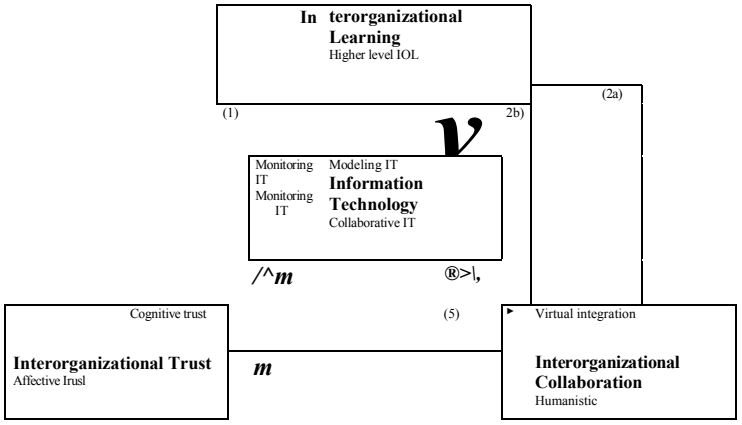

Figure I. Overview of Model of IT Facilitation of Interorganizational Learning

The primary unit of analysis in this study is the industry. Embedded units include the sector, organization, or strategic business unit and the IT [82]. The study combines units of analysis, justified by the context and the insights it provides. Grounded theory allows for analysis by a multilevel conditional matrix, which distinguishes and links levels of conditions and consequences [37,58,73]. For example, the use of EDI in the media component sector level has productivity consequences at the industry level.

Site selection was driven by the need to find representatives in the industry. This was achieved by focusing on a consolidated industry with relatively few major players. Although similar results were predicted for organizations in the same sector of the industry for use as literal replications, contradictory results are predicted across the sectors for use as theoretical replications [82]. Data was collected for this paper as part of a larger study. Semistructured interviews and questionnaires were used for data collection from different sectors of the industry and across several functional areas. This provides multiple perspectives and synergy, and strengthens the efficiency, objectivity, and pattern recognition in data gathering and triangulation. In turn this helps establish external, construct, and internal validity and reliability of the data [16, 37, 58].

Data Collection

Interviews were conducted from June 1994 to December 1994 with executives (CEO, CFO, COO, CIO, and engineering, marketing, manufacturing, and other managers) in firms along the entire value chain in the disk drive industry (see Table 1). The firms are classified into (1) drive companies that assemble the disk, head, and semiconductor components, (2) disk media, which is produced by sputtering electromagnetic material on the substrate (3) head and semiconductor firms, and (4) substrate suppliers. The study includes a total of 69 separate interviews, each with a different executive, as well as several plant tours at six drive, four media, five head and semiconductor,

Table 1. Interviews Classified by Industry Sector and Executive Function

	Drive	Disk Media	Head/Semi	Substrate	Totals
CEO	2	1	2	2	7
CFO	0	2	1	1	4
COO	1	0	2	1	4
CIO/MIS	2	4	6	2	14
Engineering	4	2	4	2	12
Marketing	3	1	1	1	6
Manufacturing	3	3	4	1	11
Others	3	4	1	3	11
Totals	18	17	21	13	69

and two substrate supplier firms. There were multiple interviews in all but three of the firms. External and internal documents help to corroborate the findings [16]. Interviews ranged from 30 to 90 minutes, and were taped and later transcribed into electronic documents. Most of the major players in the disk drive industry were interviewed and thus the sample is close to and representative of the population in this consolidated industry.

IDEMA (International Disk Drive Equipment Manufacturers Association), and Disk/Trend, an industry consulting firm, provided initial contact and entry in the industry. Both IDEMA and Disk/Trend sponsored the author's attendance at an industry symposium and recommended research participants. In addition, the author presented preliminary findings to IDEMA executives to increase participation.

Data Analysis

The study used an iterative approach for data collection, coding, and analysis. Patterns of similarities and differences with regard to organizational forms, interorganizational learning, trust, and use of IT were coded. Electronic search of the interview documents supplemented manual coding. This technique of open coding categorized concepts that were then used to develop relationships through axial coding and finally to develop a conceptual framework [73]. Although the qualitative analysis is subjective and interpretive, it produces insights on interorganizational relationships that would have been missed by quantitative analysis. The interviews yielded multiple perspectives from the range of functional groups—customers versus suppliers and all the stages along the industry value chain (see Table 1 and 2). This increased the credibility and the rigor of the findings [16], as did the fact that there was participation of representatives from most of the industry's major players.

Research Results

IN THIS STUDY, FOLLOWING THE GUIDELINES OF GROUNDED THEORY [73], I examine the phenomenon of virtual integration, an IT-enabled form of collaboration, in the context

Table 2. Participating Firms Profile

Disk Drive Industry Sector	Number of Firms	Average Net Sales Millions $ (1994)	Average # Employees (1994)
Drives	6	1,507	5,499
Media	4	392.4	2,635
Heads/Semiconductors	5	505	10,027
Substrate	2	N/A	N/A

of the disk drive industry and focus on IT and trust as intervening conditions for an IOL action/interactional strategy (see Figure 2). Thus virtual integration (collaboration), the disk drive industry context, IT, trust, and IOL are the core categories of this analysis.

Virtual Integration in the Disk Drive Industry

Virtual integration is a characteristic of the disk drive industry. The motivation is concern about being totally dependent on in-house development and production. Collaborating more closely with suppliers than in traditional business relationships gains many of the benefits of vertical integration. For example, an engineering manager, in a component design firm, explains how and why his engineers are in demand to collaborate closely as suppliers, despite internal development at drive companies.

> Disk drive companies are interested in us as a supplier, even though many of them are doing their own internal development, too. But they don't want to be totally dependent on internal development, because if for some reason, if there's a design problem or two or three and they need this equipment. And they're so much dependent on any of these critical aspects. If such a situation were to happen, it would take anywhere from six months to a year to recover from such a situation.

Design problems or equipment failures in-house might threaten the ability of the business to deliver new products on time to customers. Products are so complex that initiating collaboration after a failure would be ineffective. Similarly, the following disk division of a drive company used suppliers to reduce risks from production problems.

> *CFO:* Also, it's possible that something disastrous would happen to [us]. We could have a flood or earthquake or something. Or, we could have something much more mundane. We could just have a process problem. We could have some gas leak, or something. Temperatures could be fluctuating. Our product could fall out of spec. And we want to be able to fall back on another supplier. So, it benefits the company to not go one hundred percent. And we kind of set seventy-five to eighty percent as probably the ceiling.

Despite having efficient, high-capacity innovative equipment and low-cost internal production, this CFO saw the need for redundancy to "fall back on another supplier."

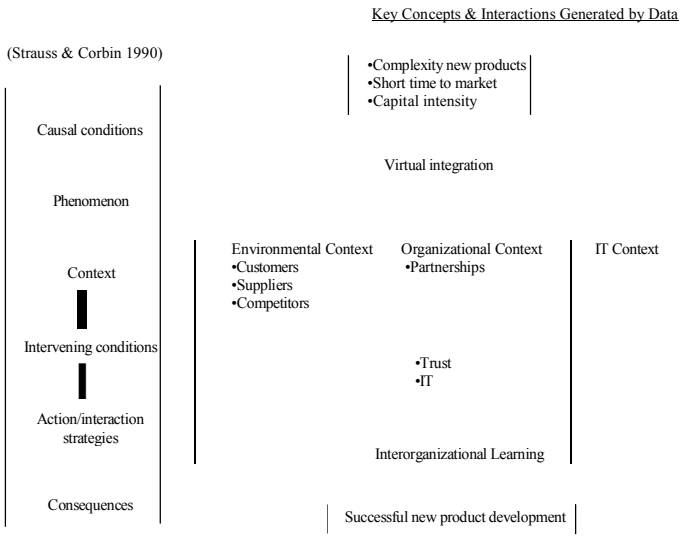

Figure 2. Application of Grounded Theory to IT Facilitation of Interorganizational Learning

To manage risks, virtual integration ("outside") often coexists with cost-effective vertical integration ("in house"). Virtual integration also promotes learning new technology or a new capability from partners.

> *Marketing Manager of Major Component Supplier:* They've tended to produce, if you will, the mainstream products in-house. They believe they can do that cost-effectively and it works to their advantage from a cost standpoint. I expect they'll continue to do that. And several other companies have similar operating philosophies, so, from a vertical standpoint, I don't see vertical strategies going away. But I see an increased dependence on outside suppliers bringing in new technology or new capability in assuring the user of being on time to market with new technology.

This learning by grafting or imitation [22,27] is a form of IOL associated with virtual integration. It also motivates the following manager in a vertically integrated drive firm to collaborate with the "outside":

> I want to keep ... us flexible. I want to keep the asset base low. Now, also, you have to put enough outside [the organization] to kind of know what's happening. I mean, I actually think if you build everything yourself, you can miss a technology step. Or, you can be surprised by—something can blindside you. So, I want to build outside because, who knows? I might have missed glass media or something along those lines. And if you're going to buy outside, you have to put enough outside that you can be—remain competitive.

If and when the drive partners learn this new capability (e.g., glass media), they may incorporate the technology capability in their mainstream products. In the next section I describe the context in the disk drive industry to gain a deeper understanding of virtual integration and the process of IOL.

Context in the Disk Drive Industry

In this section I describe the strategic environment in the disk drive industry and the influence of customers, suppliers, and competitors on IOL. Virtual integration and trust both directly and indirectly influence IOL, as shown by the research model. But these effects are also influenced in form and process by the context within which they are set.

Environmental context

The disk drive industry is turbulent, with constant technological change and uncertain demand. The business is highly competitive, characterized by failures and consolidation.

> *Manager:* The disk drive business is phenomenal. The pace, the rate of change, the innovation, the competitiveness—all that stuff is really quick.

Associated with the fast pace, research participants talk about coping with chaos, unpredictability, and complexity in the industry. Focusing on core competencies and partnering are ways to cope.

> *Drive CEO:* [Our] recipe to cope with chaos in the industry, its unpredictability, and complexity, is to focus on a few core competencies. For example, [we] maintained the design of semiconductors, a core competency, although we sold our semiconductor plant. We build some of our components but also partner with world class suppliers, such as...

This CEO explains how they sold their semiconductor plant, realizing their core competency was design, not manufacturing. They partner with suppliers when building components is not a core competence. Drive firms also partner with customers.

Customers. With continual compression of new product development cycles, there is considerable pressure to innovate quickly. Customers of drives—such as computer companies, resellers, and distributors—interact with drive firms to establish broad specifications for the new product. An engineering manager describes how they get feedback on their rough plan:

> Well, it's a constant marketing approach. We are in dialogue with them, what they want, what we have. . . . And they'll say, "What do you guys have on the road map?" And we say, "What do you want?" So it's a chicken-before-egg situation. We tell them, "Okay, this is what we're thinking of doing, but it's not firm yet because we don't have enough input.... This is our approximate road

> map plan." And they say, "Okay. All right. We'll be more than glad to give you some of your input. Because we are interested in yield in building this product." So it's a constant interactive process going on and so they will say, "Okay. All right. If you can give me this and give us this product by this and this date, we're interested." So they kind of sign up on a, not contractual basis, but more of a good faith basis.

As the partners work closely together, they refine the specifications and make them more explicit, until there is informal customer commitment to the new product.

Suppliers. As the specifications become more explicit and finely tuned, the disk drive companies involve such suppliers as head and media companies to ensure that the new product is technically sound and to troubleshoot potential problems. As explained above, suppliers used for cutting edge technologies may coexist with lower-cost in-house production.

Competitors. Competition is intense; lower prices are commonly used to increase market share and only a few drive companies have survived recent consolidations. Yet although there is pressure to develop new products, resulting in short product cycles and rapid product obsolescence, competitors tend to have similar products.

> *Marketing Manager:* Most marketing opportunities say, "What can I do to get to market first? What can I do to differentiate my product? How can I pull away from the competition?" There's very definitely a bandwidth that you have to share a space with the other competitors because if [our company] has a drive a year before anybody else, okay, we'll pick up some business, but with the major OEMs that must have a first and second source, where they have a dual sourcing policy, they're not going to pick up your drive, because they don't have a second source opportunity.... They are not going to tie their wagons to one star.

Drives are interchangeable commodities. To reduce risk, most OEMs only buy those drives for which they have a second source. So, for this industry, being too innovative and too far ahead of the competition is hazardous. This motivates competitors to share information or obtain competitor information through OEMs.

Organizational context

Organizations in the disk drive industry need virtual integration to enable learning among partnering firms. Each firm focuses on its core competencies, bringing a diversity of knowledge to a partnership. At a disk drive industry conference presentation, a drive CEO explains the advantages of this virtual organizational form:

> Joint ventures, strategic partnerships, and outsourcing have been increasing as organizations become modular, virtual, and face disintegration. The net result is the availability of more resources, greater efficiency, and faster time to market. There is more management focus and investment in core competencies.

> Specifications for the lowest unit cost from suppliers is no longer the way to do business. It is important to design, integrate, and deliver on a global basis. Partnerships improve flexibility and access to new technologies. The virtual organization seems to be a single entity and is only assembled when needed. It gains the advantage of vertical integration but is also survival without capital. Large in-house suppliers have become uncompetitive because there is more tolerance of inefficiencies and decisions are not taken to fix such problems.

The disk drive industry is one with complex interrelationships between competitors, suppliers, and customers. Strategic alliances, informal partnerships, and acquisitions are common, and even competitors will coordinate and transfer technology when mutual benefits are likely. In-house suppliers, not having to compete for customers, often become less efficient, and less motivated to innovate. Also, they do not have the diversity of knowledge that is available from external sources.

IT Context

In the disk drive industry, computers are widely used in production (robotics and sophisticated automated equipment) and in engineering (computer-aided design and simulation tools). In new product development, for example, engineering transfers simulation data and design schematics, while manufacturing transfers inventory data and production plans using e-mail, videoconferencing, and EDI. Frequently, engineers log into a collaborating organization's computer to interactively simulate disk drive performance over the Internet.

New product development is capital-intensive, however, with the result that organizations often limit other IT investment. Manual procedures and inadequate legacy systems were common, at the time data was collected, although personal computers were utilized for e-mail and spreadsheet analysis. Videoconferencing capabilities were prevalent in the larger firms, but EDI was used only on a limited basis.

Intervening Conditions

Intervening conditions either facilitate or constrain action/interactional strategies [73, p. 103]. Interviews revealed that IOL strategies with customers and suppliers in the disk drive industry were facilitated by IT and constrained by lack of trust. A VP from a major successful drive company stresses the importance of IT and trust:

> So, my largest customer... and we work the same way as I try to work with our suppliers. And all of that gets facilitated over time through electronic information. But, I think that trust is ... that's what makes the difference.

Working closely with its major customer and suppliers is typical in the disk drive industry. Other interviews also emphasize the importance of trust and IT in these relationships.

Trust

Several participants give examples of affective trust development in "close relationships" and informal noncontractual commitments. According to a marketing manager at a semiconductor supplier firm, the close relationships take years to develop (face-to-face).

> [I]t's very important to understand the people you're working with, the level of experience that we've been able to garner over the years. Since this is our only business, the relationships that we've been able to establish with their engineering group and their management people, these types of levels of *trust* that are built up.

This manager emphasized the long-term aspects of social relationships that build affective trust at both management and other levels of the organization. Trust has developed from successful collaborations between engineers in the past. An engineering manager in the head/semiconductor sector also discusses trust and the strong customer relationship between engineers. Engineers develop a community-of-learning promoting collaboration.

> [W]e deal a lot with the customers at the engineering level—engineers to engineers—and develop a very strong relationship, and trust and respect. Because you have to have that.... Our engineers are highly experienced and trained in the respected business area. So my engineers ... they're being viewed by our customers as the source of information, the know-how. ... And they can converse with the customers at their level, not just very technically.

The common professional bond promotes trust [46, 77], effective communication, and mutual understanding. Drawing on past experience, the following participant illustrates cognitive trust [46] based on the partner's track record, stating, "they always use it."

> *Component supplier:* And, if indeed, it's what they said they wanted and we were able to produce what they wanted in the time frame they wanted, then they always use it. As long as they were able to define what they wanted at the time it was needed.... And then, of course, you always have to change those things as you get into the project because you don't know all the things up front that are going to occur as you proceed.

This supplier recognizes that when customers jointly characterize new products knowledge is tacit and therefore difficult to initially specify "up front" or in a contract. Instead, partners rely on trust. The following major drive company, with some in-house production, relates trust to sharing sensitive firm information and plans.

> *CEO:* The partners discuss future product plans and financials, and commit, trust, and understand cost structures, with each making a fair profit in both good and bad times, sharing a co-destiny.

Similarly, a VP of Operations at a drive company observes that trust involves sharing information and site visits to observe each other's processes. According to the VP, both partners benefit from the openness, shared knowledge and reciprocity.

> [T]rust is if you're willing to share information.... And I've actually probably been very open with my outside vendors just in order to develop a trusting relationship. I let them come through and look at my process ___ [I]t's mutually good for us to do this. They make money. We make money.

Mutual benefits from reciprocity and openness build affective trust. The VP acknowledges that suppliers may be concerned about the risk of making specific investments for a customer in a new relationship. Since the drive firm also makes the component, the supplier is vulnerable to sharing its knowledge and then being discarded.

> We're trying to pick our very first platter [disk media] partner. And, we build our own, as well. So that's an even little bit tougher one to do because they're afraid, oh my gosh, they'll make the investment and ... "we'll give [them] all our technology and then [they'll] cut us off." And so that is going to be a really interesting one [partnership].

The media supplier must trust the VP since he is in a vulnerable position and taking a risk in this type of partnership. Also concerned about the risks of partnering, a marketing manager at a leading component organization explains the influence of reputation on trust (cognitive) [46]. He is not as convinced that trust is mandatory in certain circumstances.

> Trust is half there. You know, I can't kid about the term 'partnership.'You have to be cautious of that. In the industry, it used to beat me. It's a scary thing to be a partner. . . . And it really comes down to the individuals is the gist of it—the demeanor of the individuals involved. Some command more trust and are more honorable, so to speak, than others. And you come to know that over a period of time.
>
> If you're dealing in a situation where there's a lack of trust, you need to have a product that the customer can't live without, to be safe. You don't have to [trust] if there's a real need. Yeah. It's better if you can trust each other. There's a lot of relationships in our industry, in the data storage industry, where they do operate on trust now quite successfully. And there are others that don't.

This manager expresses the personal anxiety in partnerships and the relative importance of trust. He distinguishes between trust (affective) and "need" (rational) relationships, implying that there are some risks and potential disappointments. He would prefer trust (affective), yet is willing to take risks when the customer has a dire need of his product.

Despite the risk of being left with obsolete inventory from canceled orders, suppliers try to leverage their designs to benefit from economies of scale. They perceive the risk to be less with customers in long-term relationships that have built up trust.

Contracts are rarely used and commitments are generally informal, based on trust, relationships, and a belief that legal contracts are not effective.

> *VP at a Major Drive Company:* [W]e have no contract with these people. We sort of have a memorandum of understanding which looks a lot like the vows of marriage. I mean, you know. If you treat me well and I treat you well, we'll go on forever.

This VP believes reciprocity generates enough trust (affective) to bond the relationship informally without a contract. An effective collaboration reinforces trust, and trust encourages further collaboration. IT also plays a role in trust, collaboration, and IOL.

Information Technology

IT can facilitate trust, collaboration, and IOL. New product development in the disk drive industry is strongly dependent on IT in several ways. For example, drive sector tracking systems evaluate suppliers' quality, on-time delivery, and other performance attributes for quarterly reviews. A good track record builds cognitive trust, and the regular feedback keeps suppliers vigilant and learning, since notwithstanding trust and close relationships, if a supplier falls below a certain rating he loses certification. For participant comments on IT monitoring of suppliers, see Table 3.

Another use of IT is to manipulate and share component designs. Engineers specify various parameters and test performance, creating new knowledge without needing to build physical models. This interaction supports shared higher-level learning about the assumptions underlying the model and improves model representation.

> *Semiconductor Supplier Engineering Manager:* So there's a big, continuous feedback loop on the whole CAD modeling tool system. We're even looking at how do you tie that in to the customer? Because they're even looking at a higher level model. How do you tie those models in with our models? ... We do a lot of design experiment things where we'll skew products on one side of distribution or another. How do you categorize all of that, put it in their system, let them run their models, feed that back into our system. All of it then goes back into our modeling and ...

The feedback loop, tying models together and integrating simulation tools, can cut down on the number of iterations, enhance learning, and dramatically reduce design time to market. Similarly, another IT modeling tool, a physical prototype, promotes higher-level learning by surfacing assumptions. 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.

> *Engineering Manager:* 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

Table 3. IT Monitoring Suppliers

- The report is produced by a DSS developed by a user. Data is pulled out of the manufacturing database and transferred to a spreadsheet. We give suppliers feedback at the quarterly meeting. Some criteria (with weightings) for the vendor ratings are: quality 15, delivery 25, technology 15, cost 10 and customer satisfaction 10.
- Most significant is the maturing of the drive manufacturers detailed quarterly review, with very direct measures of quality, service and technology. Every quarter it gets better; it is an iterative process.
- We have many single source suppliers and focus on yield—we mon/for yield status, and select suppliers that can keep up the ramp.
- Well, it's not like we operate blind, though. So, again, we try to measure an awful lot of things.

> 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.

This engineering manager finds the model more intuitive than drawings and it helps to communicate the design and troubleshoot any problems. The prototype addresses producibility issues, making design reviews more productive and facilitating higher-level learning. Despite the advantages of collaboration, sharing information on product plans and inventory levels externally over networks has risks.

> *Drive CEO:* Teams work together concurrently, in real time using networks to communicate future product plans and inventory levels. This is not possible with many suppliers. It is a balancing act with not more than two or three players. There are risks that you could lose control of a function, but integrity and honesty ensure proprietary information does not leak out.

This CEO controls the risk of leaking proprietary information by restricting real-time access and collaboration to his most trusted suppliers. In this case, both cognitive trust (integrity) and IT are necessary for interorganizational collaboration.

Communication between firms during the knowledge creation process benefits from technologies such as e-mail and videoconferencing. Engineers use e-mail to transfer design data from simulations and test results and to troubleshoot and solve technical design problems. Inventory information, production plans, and purchase orders are also distributed electronically through e-mail, videoconferencing, the Internet, and EDI.

The rapid communication and turnaround enables feedback, better coordination, and IOL, which improves the performance of both firms in terms of faster time to market of new products, just-in-time IT deliveries, and reduced lead times. For example, e-mail removes physical barriers between organizations:

> *Semiconductor CIO:* [W]e want to advance the state of the art in our network e-mail systems [used internally and for communicating with customers and suppliers] ... totally. Totally... in the world, right? Yeah. Internally and externally. Because email, what it does is remove—it removes the physical barriers.... It doesn't matter that you're on different times? No. None of that.

Collaboration becomes easier through IT. Even this manufacturing manager (of the same semiconductor supplier) who is less enthusiastic about email, acknowledges IT's value for bridging time zones offshore. "We have email, but most of the communication is voice mail. We do have the offshore connections on the email, though, in some cases."

This engineering manager of a head supplier prefers faxes, since he gets too many e-mails: "Oh, I mean, we couldn't live without faxes.... e-mail is a nuisance, in my opinion."

The cynical attitude that some participants had toward IT shows a need to train employees to use computer-mediated communication effectively. The following engineering manager, from a semiconductor supplier, discusses plans to make information from faxes accessible on-line for customers:

> You never know who's been copying the faxes and faxes and faxes, and you end up with stacks of paper like this every day. No one reads it anyway, until you call them and ask them to. And then they bitch and moan that they didn't get the information. But they had the information. So, what we're talking about with a couple of our customers is actually putting on-line servers so the pertinent information that would be used [by] multiple functions in a customer, they can just get it on-line, and they can get it as it happens.

This suggestion would use IT to improve an interorganizational collaboration and promote virtual integration. Another collaborative IT, videoconferencing, is being used successfully by some organizations to substitute for or complement face-to-face interaction. Videoconferencing's media richness, and interactive communication and coordination capabilities cross geographical, departmental, and organizational boundaries.

> *Top Manager:* 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.

This manager realizes that "seeing" collaborators is important for picking up body language cues, promoting trust, and enabling negotiation. Videoconferencing enables engineer-to-engineer interorganizational communication and problem solving in real time, and the feasibility of "getting a lot more people involved. ..."

> *Top Manager:* Let's say we have a technical issue with Compaq in Houston, okay? You know, seven or eight years ago, we would fly three people down there and talk to them about it and see what [was needed to resolve it] .. . and then we'd fly back and do that. Well now, we can have a meeting where we can have twenty engineers going through all the data and looking at it and talking about it with their engineers there. And no one flew anywhere. And sit there and get a lot more people involved and look at it [through videoconferencing].

Increasing the number of participants in the interorganizational collaboration introduces a greater diversity of knowledge. Despite the advantages, some executives believed that communication technologies could not successfully replace face-to-face meetings. They stressed the need for communication with body language and felt it was essential for negotiation, building trust, and getting to the root of an issue. Furthermore, some managers were skeptical of the value added by communication technologies, considering the cost in dollars and time. Table 4 shows some examples from the interviews that illustrate limitations of IT to facilitate IOL. Nevertheless, once trust is established face-to-face and leads to close collaboration in a community-of-learning, then IT is often used to speed up communications as well as for monitoring and modeling.

Interorganizational Learning Action/Interaction Strategy

An IOL strategy, although potentially benefiting from IT, relies on face-to-face meetings to build trust and to encourage close collaboration. Because of the high degree of interdependence between firms that use virtual integration, and the difficulty of transferring tacit knowledge for IOL, disk drive firms work closely with their vendors if they outsource production. A Quantum manager explains the importance of site visits by product designers to outsourced manufacturing operations at MKE.

> So [MKE] were doing high-volume manufacturing, which is why we slid right in and learned a ton from them.… I think we could learn from each other a lot more. I think we learned a lot. U.S. design learned a lot about discipline. And we in this factory have begun to learn a lot about automation and how to run a high-volume factory.... We don't share outright in terms of they don't supply automation for us. But we have teams that go back and forth. Like we are trying to automate [x] and they've done that before so we sent a team over there. We take our drawings so we share. Manufacturing types know no boundaries. They are not sophisticated enough in a business sense to worry about who does what to who[m]. It's just somebody has a neat toy, let's go and look at it and see if we can use it.

Quantum teams share design drawings and learn discipline and automation from MKE. It would be difficult to accomplish this and build trust and close collaboration without face-to-face meetings during site visits. By collaborating, each partner gains a diversity of knowledge and the stimulation to reconsider assumptions and organizational

Table 4. Limitations of IT to Facilitate Interorganizational Learning

E-mail

- But what makes me crazy is ... before you separated everybody they had full jobs now you are adding ... keeping up on your voice mail, your e-mail, your videoconferencing schedule.
- The only complaint I've ever had about email systems ... is that you can't make it be a substitute for what I would call verbal or face-to-face communication___ If you sit down and talk to somebody and you've got a problem, you'll resolve that problem, because you can't... you won't leave the meeting without getting a resolution to the issue. Email is very hard to do that, because you can email back and forth for days without solving issues.... Issues have got to be resolved with confrontation, ... face-to-face...

Videoconferencing

- Yeah. It works okay. I'm not sure the value add you get from the video is enough to warrant what the likely extra cost is.
- Well, I think face-to-face meetings are required when you're trying to demonstrate emphasis or priorities or the vision.
- The real issue is you have to learn your messages have to be quick. They have to be simple and you cannot have touchy-feely discussions over this. You cannot get to the root of the issue because the so much of how you communicate is with body language and inflections. When someone goes like that (gesture) they are asking you to hold on. When someone goes like this (gesture) you are ticking them off. You miss all that on videoconferencing.

routines. Similarly, a semiconductor supplier works closely and shares knowledge with foundries (outsourced semiconductor factories) to develop new processes and to improve yields.

> *Marketing Manager:* For developing new processes, for example, we work closely with our foundries to develop new technologies and new processes. So we're very involved in the manufacturing process. But we don't have to spend half a billion dollars a year or something on new fabs [factories]. We do our own analysis. When we see a problem, obviously we expect the foundries to do an analysis, also, and fix it . . . but we will tell them, "You have problems in metallization. Second metallization layer __ "Whatever. We'll try and identify problems.

Learning through working closely together, solving problems, helping each other, and sharing knowledge is also evident at the following media division of a drive company.

> *Media Executive:* One of the things that we had to develop is a second source. We work close with them to help. And they help us, too. We've actually lately ... we've had a hard time with our outside vendors being able to make the disk that we need. We've spent a lot more time us trying to help them make it.
>
> Interviewer: But doesn't that concern you that you're giving away the jewels, or... ?

> *Media Executive:* It's something we watch. But, again, we're doing it for our own benefit.... I think the risks of doing that are worth the benefits I have by having a second source. And I benchmark the process. Because they have the same concern that we learn from their technology and obviously apply it to our own internal users, too.
>
> Interviewer: Oh. So you learn from each other? What do you do with this problem?
>
> *Media Executive:* Yeah. And so it's kind of a ... you have to give a little to get a little.

Second sourcing provides an opportunity for IOL and a competitive benchmark for internal production. Disk drive firms use customers and suppliers as sources of ideas. They learn through benchmarking, observation during site visits, imitation, and interactions. IOL takes place as needs and capabilities are defined collaboratively. There is a trend to begin the interaction earlier in the new product development process. "I think buyers and sellers are getting closer together in terms of working earlier in the process to define needs and capabilities."

An earlier collaboration introduces more potential benefits. However, close relationships take time and resources, so this restricts collaboration to a limited number of suppliers.

> *Drive Executive:* To do this kind of work, you cannot have five suppliers of everything. You have to have one or two. You have to be very close because they all have to control their quality and their processes, as well—or, because we're only as strong as our suppliers on many things. I mean, we can have the best quality in the world and if we get contaminated [disk drive] heads, then we're all screwed up. So, we have primarily one head supplier, at least on the front end. And they produce more than . . . or they give us more than fifty percent of our heads. And then we have a couple of other suppliers. Actually, we're trying to get down to two for almost everything. And then we're in the process of supplier reduction. Virtual vertical integration, we call it. And so we had to develop a very close relationship.

To control quality and processes, partners interact and provide feedback to each other. Organizations learn from each other as they share experiences, resources, and information. Firms exploit complementary capabilities as they co-design new products. They cross organizational boundaries to exchange feedback, control quality and process knowledge, perform experiments, and share product plans, financials, and cost structures.

> We have open book costing. . . . They have engineers that live here. We have engineers that live there. Their salesman lives here, you know, and we're his only account. It's a possibility that they will take over a part of our Engineering group, because as we see different pieces of silicon moving together, it may be better for them to go work closely with the group that's already with

this particular supplier, and co-design a single chip instead of us designing one and them designing one.

Interorganizational collaboration through co-location with frequent face-to-face contact builds affective trust. Cognitive trust among cohabiting engineers increases as they observe each other's competence and reliability. Based on developing trust, an engineering community-of-learning encourages further interorganizational collaboration, such as product co-design, and IOL. Over time, the partners learn to become more adept at collaboration and trusting each other. This reinforces IOL.

New product development requires a diversity of expertise because it is increasingly technically complex and capital-intensive. Thus it is often a cooperative venture that involves customers and suppliers as well as many of the functions within the organization. Organizations learn from each other as they communicate electronically and visit each other's sites. The visits improve process control, reduce the frequency of quality inspections, resolve quality problems and design issues, and certify new products.

In the disk drive industry, this study found similar results in the same sectors—literal replications—and limited contradictory results across sectors—theoretical replications. For example, in the drive sector, tracking supplier performance was the norm and trust was assumed, yet a manager in the component sector was more skeptical about the universality of trust. Such different perspectives are not surprising and were explained by deepening the analysis on trust.

Discussion

EXAMPLES FROM THE DISK DRIVE INDUSTRY DEMONSTRATE the significance and applicability of mutual learning across organizational boundaries. Examining the motivation for such virtual integration provides insights into understanding why IT facilitates IOL.

Interorganizational Learning as Motivation for Virtual Integration

Virtual integration in the disk drive industry is driven by the complexity and high capital intensity of new product development. Firms need complementary knowledge and expertise, specialized competencies, diversity, and resources. Firms are dependent on suppliers to bring solutions in their area of technology. Because of the short time to market of new products, knowledge needs to be exchanged electronically for fast response and feedback. Table 5 summarizes the differences between vertical integration (VI), virtual integration, and markets.

Historically, disk drive firms manufactured components in-house. Some larger firms continue to find VI a cost-effective strategy. Moreover, VI is proposed for high-tech industries that have product complexity [12, 44], asset specificity [44], and need control over sources of supply and leverage over vendors [70] due to uncertain demand [12].

Table 5. Comparison of Vertical and Virtual Integration and Markets

	Vertical Integration	Virtual Integration	Market
Production	In-house	Outsource	Outsource
Collaboration	Close	Close	Arms length
Motivate innovation	Low	High	High
Risk production problems	High	Low	Low
Risk of losing control of supply	Lowest	Medium	Highest

When technologies and markets are fast-changing, however, VI limits an organization's learning potential by insulating the firm from market changes that pressure the firm to redefine its core competence [70]. On the other hand, interorganizational collaboration enhances learning by introducing new knowledge and a diversity of ideas into the firm. Such virtual integration stimulates higher-level learning through reevaluation of current practices [15]. Larger firms often use a combination of both vertical and virtual integration, balancing VI's economy of scale cost reduction advantages with virtual integration's strength for interorganizational learning.

Larger firms cater to these needs on a contingent basis, as illustrated by the practice of using suppliers to provide disk media components even when the capability is in-house. This reduces the risk of dependency on one supply source, prevents complacency, and motivates innovation and interorganizational learning. Smaller firms in the industry are especially dependent on virtual integration, since they do not have the capital to invest in the expertise and equipment needed for VI.

Apart from explaining "why," another objective of this paper is to explain "how" IT facilitates IOL. Due to a lack of existing models, this research generates a new conceptual model, which integrates the grounded theory analysis of the interviews with the research literature to increase generalizability [16, 18, 58]. Numbers in parentheses on the conceptual model (Figure 3), are referenced in the following discussion. The model shows four different mechanisms of how IT facilitates IOL: (1), (2b) and a combination of (3, 2a) and (6, 5, 2a). Furthermore, the model shows relationships among trust, collaboration, IT, and interorganizational learning. Interactions with the disk drive industry context provide further insights and add richness to the analysis.

How IT Facilitates Interorganizational Learning and Collaboration

IT increases the range, amount, and velocity of information flow spanning boundaries within the organization, between organizations, and across time and space [53]. Interactive electronic feedback [2] and electronic distribution of information and knowledge [27] facilitate IOL. Based on the interviews, participants' use of IT can be classified into monitoring suppliers (1), interactive modeling (2b), and communication with partners (3). IT's important role measuring, monitoring, and controlling [21,57] is explained first.

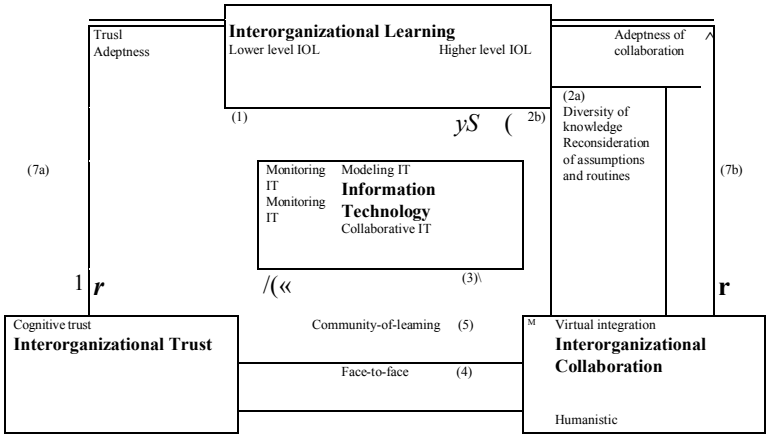

Figure 3. Conceptual Model of IT Facilitation of Interorganizational Learning
Note: Dashed lines indicate a weaker impact than solid lines.

(1) There is a distinction between lower-level and higher-level IOL. In lower-level IOL, one or more organizations adjust their behavior in response to feedback acquired in the collaboration. For example, Quantum engineers adjust their designs based on feedback from MKE on manufacturability. Quantum and MKE have put a tremendous effort into knowledge exchange, which has paid off in a joint capability for superior designs, high yields, and low rework that competitors find difficult to imitate [40].

Similarly, Conner adjusted its disk drive specifications to meet Compaq's and other customers' requirements. Component vendors adjust their outsourced production from feedback given by quality personnel who work with foundries to improve yields and troubleshoot problems. Disk drive firms monitor and track suppliers based on quality, yields, delivery, and other criteria. Their quarterly feedback induces suppliers to adjust their behavior rather than risk losing their certification status.

IT facilitates lower-level IOL through monitoring. For example, suppliers receive reports on their quarterly performance from the output of decision support systems or spreadsheets. Email, fax, and videoconferencing augment face-to-face meetings for feedback on yields and production problems involving explicit knowledge.

(2a) Higher-level IOL challenges assumptions and establishes new routines when organizations institutionalize new learning processes. For example, after collaborating with MKE over time, Quantum engineers internalized and routinized the mentality of design for manufacturability. Similarly, long-term customers and suppliers may influence new routines for design and production in disk drive companies. In another example, second source vendors provide access to new technology for in-house media organizations. They may change their processes upon learning new ideas.

Through inter-partner learning, organizations gain skills and a diversity of knowledge that they could neither readily create nor acquire inside the organizational bound-

aries [22,61]. However, external knowledge is often tacit and not readily transferable because it is difficult to articulate and encompasses context specific skills [22, 55,77, 81]. Socialization in close relationships attempts to overcome these barriers to learning [55]. IT facilitates higher-level IOL indirectly through collaboration and directly with modeling technologies.

(2b) During the new product development process, computer simulations enable knowledge creation through experimentation with multiple plans. This is known as the internalization knowledge creation mode [55]. Engineers do experiments and transfer simulation files interorganizationally. Simulation information may challenge assumptions and leads to changes in production or design routines. Simulations help engineers convert explicit knowledge (originating across boundaries) to tacit knowledge with many iterations of "what if scenarios. Since there are minimal incremental costs to extended interactions, knowledge is refined by iterative feedback from results of trial and error variations. Participants learn more effectively since the answer arrives while the question is still fresh in the modeler's mind [47]. Models that are physical or virtual also enhance the externalization knowledge creation mode [55] by making tacit understandings of specifications explicit. The prototype becomes a source of discussion for "mutual adjustment" and prevents misunderstandings from perpetuating.

(3) Collaborative IT, such as communication technologies, enable interorganizational collaboration (IOC), overcoming physical, temporal, and organizational barriers. For example, email, videoconferencing, and faxes reinforce the lack of formal contracts by supporting informal connections between firms. They are relatively easy to use for IOC since they do not require special investment, they are nonspecific to the partnership, and they offer flexibility in the amount of information distributed and the frequency of contact. In contrast, the lack of standardization of EDI at the time of the interviews mandated four to five different software systems for one participant to communicate with each customer. The result was limited flexibility and fewer informal connections.

It is important to differentiate between IOC and IOL. Collaboration is defined (by Roget's Thesaurus) as working together, while organizational learning is defined as a change in behavior or belief [27]. At the interorganizational level, collaboration can take place without learning. This would happen during routine processes when neither partner needed to adjust its behavior. On the other hand, IOL involves new skills or knowledge for at least one of the partners. Trust is important for IOL to take place.

Overcoming Lack of Trust—A Barrier to IT Facilitation of Interorganizational Learning

(4) Essential components of interorganizational learning are communication, dialogue, and coordination. Whereas electronic communication is preferable when distance and time zones are obstacles to fast response, early in the relationship face-to-face communication is ideal to establish trust and prevent misunderstandings. Although IT has the potential to remove barriers of time and space [23,71] and the boundary of the organization itself [32], face-to-face interaction reinforces strong ties by building

affective trust [33, 53, 59, 71]. If the communication is frequent, emotionally intense, and involves the sharing of confidences and reciprocity, then the social interaction is considered a strong tie based on trust [19]. Strong ties are needed for IOL during new product development to cope with complex, ambiguous information, uncertainty, intense interaction, and the urgency in highly competitive industries to reduce time to market. Face-to-face offers the capacity for interruption, feedback, and learning, and invokes all five senses and psycho-emotional reactions. Furthermore, copresence of participants provides social context cues that build trust [71].

Thus face-to-face interaction is most valuable where information is difficult to verbalize, situations require high levels of interaction to communicate complex information [5], or under uncertainty and ambiguity [53]. Similarly, tacit knowledge is often acquired and transferred through observation, imitation, practice, and shared experiences based on trust. In other words, "the mere transfer of information will often make little sense if it is abstracted from embedded emotions and nuanced contexts that are associated with shared experiences" [55].

Interorganizational (or mutual) trust is promoted by the knowledge of mutual benefits [15], such as shorter time to market for new disk drive products. This expectation is reinforced by the impact of the occupational community—such as engineers—and reciprocity. Reciprocity, a practice of give and take, builds affective trust in a partnership [28], and is associated with strong ties based on trust [19] and group-based trust [8].

(5) Reciprocity and communities-of-learning are features of collaboration that both build trust and encourage further collaboration. Collaboration is important for maintaining trust [15, 61], and prior social ties "contribute a base of common values and social similarities that facilitate interactions and communications ..., mutual trust, and respect" [8]. Similarly, informal, interpersonal relationships and communications promote trust [15]. For example, engineers or other occupational communities form "invisible colleges" of peers trading know-how [15, 77], identifying with each other and promoting trust [49]. Trust is often instantaneous because of a common profession such as engineering—engineer-to-engineer links are strengthened by the common occupational culture. This trust facilitates collaboration.

(6) Although some firms betray trust by their intention to internalize their partner's skills to compete [22], typically each partner learns from the other while sticking to their respective specialty. While component manufacturers do not use IT to monitor customers, IT is widely used to monitor suppliers. Monitoring helps to build cognitive trust [46] by checking competence, reliability, and credibility [3, 50]. Once cognitive trust is established, affective trust and stronger ties develop—primarily face-to-face—resulting in openness and greater information sharing. After gaining both cognitive and affective trust, firms use IT to facilitate information sharing with modeling and communication technologies.

(7) IOL promotes trust and collaboration as organizations learn to trust (7a) and learn to collaborate (7b) [41,61]. "[Trust] is learned and reinforced, hence a product of ongoing interaction and discussion" [61]. Specific knowledge transfer and adeptness of collaboration are two processes of learning that occur simultaneously and

recursively from exploration and experience with collaborations. Firms learn to become "adept at and reputed for the general practice of collaboration with diverse partners" [61]. The next section draws conclusions about IT facilitation of IOL from the analysis above.

Conclusion

THE CONCEPTUAL MODEL IN THIS RESEARCH focuses on the interorganizational dimension of learning and knowledge creation, with emphasis on the role of IT and trust as enabling factors. The need for organizations to learn from each other and recent developments in IT, such as business-to-business electronic commerce, supply chain management, customer relationship management, and processware software, highlight the importance of facilitating IOL with IT. Unlike previous research, this paper explains how and why IT facilitates IOL. Researchers in strategy have studied IOC and IOL [20,22,61], but overlooked some salient IT issues, while IT researchers have emphasized interorganizational information systems [9, 25,62, 64] and the virtual aspect of collaboration, but glossed over aspects of IOL [63].

Virtual integration in the disk drive industry explains why IT facilitates IOL. Because of the complexity of new products and the capital intensity in the disk drive industry, organizations want and need to be exposed to and learn from their partners' innovations. They cannot afford to be dependent on internal expertise, so IOL is the motivational key for collaboration. Facilitation of the IOL process with IT helps cope with geographical dispersion and the pressure to bring new products to market quickly.

Contrary to previous research that predicts IT contributes to the demise of vertical integration [44], the disk drive industry uses a combination of VI and virtual integration instead of markets. Although previous research has not proposed that virtual integration coexists with VI for the same product, this paper explains this counterintuitive phenomenon.

This research integrates multiple perspectives and emphasizes IOL. The integrative conclusion goes beyond more static roles for IT by integrating findings from several sources into the model in Figure 3. This model focuses on how IT facilitates IOL, and is new in explaining the mechanism of this facilitation. It differentiates between facilitation of lower- and higher-level interorganizational learning, cognitive and affective trust, and virtual and humanistic interorganizational collaboration.

IT facilitates IOL in two direct and two indirect ways, as shown in the model in Figure 3. In the first direct way, IT facilitates lower-level learning via a feedback mechanism using explicit knowledge encoded in information systems. IT monitors and tracks inventory levels, orders, and quality performance in a timely manner. The immediate or fast feedback enables the partners to adjust their behavior for quick response and increased efficiency. For example, suppliers respond to performance reports and documents delivered by EDI or the Internet. In the second direct way, IT facilitates high-level IOL using modeling technologies.

IT facilitates IOL indirectly in two more ways. By tracking supplier performance, IT monitors the partner, providing evidence of reliability, which induces cognitive

trust, which encourages further collaboration and then IOL. This insight may be new to the IT literature.

Finally, IT facilitates IOL indirectly by improving collaboration. Email and videoconferencing allow partners to discuss and explain issues despite organizational, geographic, or time barriers. This exposes partners to a diversity of knowledge that may encourage change in organizational routines. In such higher-level IOL, tacit knowledge as well as explicit knowledge is involved. Other links in the model explain the relationship between trust and collaboration and the completion of the cycle when IOL adeptness improves trust and collaboration [61]. In summary, IT facilitates lower-level IOL directly, while it indirectly influences higher-level IOL through facilitation of cognitive trust and virtual collaboration.

Implications for Management

Understanding how and why IT facilitates IOL in the disk drive industry is useful to management in general. In almost every industry, it is no longer sufficient to focus on internal productivity. Collaboration with customers, suppliers, and other firms is the key to future prosperity.

During the new product development process, complex technical information is difficult to communicate initially because it is incompletely specified. However, such tacit knowledge becomes explicit as product and manufacturing processes develop through shared problem solving. While IT improves efficiencies in lower-level IOL, the IT mechanism for higher-level IOL, apart from modeling, is usually through trust and collaboration. IT's role is to measure reliability, which increases cognitive trust, as well as promote collaboration through electronic networks.

Management needs to be receptive to opportunities for exploiting IT capabilities, yet realize IT limitations, both short-term and long-term. Some limitations of IT may lessen as IT performance improves relative to cost. Computer simulation tools are becoming more efficient and cost-effective, increased bandwidth and possibly virtual reality techniques will improve videoconferencing [56], and improved graphical user interfaces will help overcome resistance to IT. Management should assess IT for its business value. Underinvestment in IT was common in the disk drive industry. Nevertheless, IT cannot always substitute for face-to-face communications. Management should understand the importance of high levels of interaction, feedback, and interruptions for effective learning, with emphasis on social context and sensory cues and shared experiences. This will initiate trust-based relationships and complex, ambiguous, or tacit information [5,53, 55, 71]. Despite these limitations, management needs to create a culture that knows how to exploit IT. For example, the high risk from excessive inventory that rapidly becomes obsolete has been a recurring problem in the disk drive industry, yet a lack of standards has resulted in minimal use of EDI. Collaboration at the industry level could determine standards, or alternatively use the Internet for collaborative forecasting for supply chain management or business-to-business electronic commerce.

Implications for Research

Most IT research on interorganizational processes has focused on interorganizational systems [9, 64] such as EDI [25, 62], and more recently the Internet, but ignored the mechanism of how IT facilitates IOL. This study's contribution is clarification of this mechanism for both lower-level and higher-level IOL. IOL is likely to become increasingly important as organizations search for complementary capabilities in partners. Similarly, the use and sophistication of IT is constantly improving and increasingly important for almost every industry.

Finally, this work provides rich context and insights on an important U.S. industry. The impact of IT on IOL is likely to increase with further collaborations, adoption of supply chain management software, and developments in business-to-business electronic commerce.

Limitations and Proposed Extensions to the Work

Trust has been identified as essential for IT to facilitate interorganizational learning. Extensions to this work could analyze other enablers such as intent [22, 55], transparency, receptivity [22], redundancy, autonomy, fluctuation, and requisite variety [55]. This research analyzed interorganizational relationships and learning, trust, and the strengths and weaknesses of IT facilitation of IOL in the disk drive industry. The one-industry focus allows an in-depth analysis and controls for industry and environmental effects. However, since the data in this study is limited to the disk drive industry—an industry that is highly competitive, fast-changing and technologically complex—the findings may not be generalizable to industries that do not share these characteristics, although increasingly most industries do. Consequently, a proposed extension to this work would involve data collection over diverse industries to improve external validity.

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