Collaborative Activities in Virtual Settings: A Knowledge Management Perspective of Telemedicine

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ABSTRACT: Advances in information and communications technology have made possible collaborative activities in virtual settings. Virtual settings can significantly expand the knowledge resources available, yet they also create additional challenges to the already difficult activities of collaborating. The purpose of this research is to provide a better understanding of how collaborative activities in virtual settings enable the different parties to achieve their desired objectives by examining them from a knowledge management perspective. Three aspects of knowledge management—knowledge transfer, knowledge discovery, and knowledge creation—are examined in the context of telemedicine projects. The findings indicate that an association exists between the types of collaborative activities engaged in virtual settings and the effects such projects are perceived as having. While this research focuses only on virtual collaborative activities in health care, it is likely that these findings are applicable to other industries engaged in such activities in virtual settings.

KEY WORDS AND PHRASES: collaboration, knowledge management, telemedicine, virtual teams.

COLLABORATIVE ACTIVITIES ARE AN EFFICIENT and effective means to apply the ever more varied and specialized knowledge required in today's rapidly changing environment. Collaborative activities involve two or more parties working together to

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achieve the desired outcomes the parties would find difficult or impossible to achieve on their own [17, 47]. Advances in information and communications technology (ICTs) have made possible collaborative activities in virtual settings, where the use of information technology (IT) as the primary means of connection has overcome geographical barriers. Collaborative activities in virtual settings have significantly expanded the knowledge network available, providing increased access to even more specialized knowledge more rapidly and at a lower cost [1, 51].

Yet virtual settings create additional challenges to the already difficult activities of collaborating. Tacit knowledge has a personal component [43] that makes it difficult to communicate to others in an understandable form, and the reliance on ICTs as the primary conduit for such communication significantly increases the difficulty of engaging in collaborative activities. Collaborative activities are social processes requiring a rich, supportive environment; however, such environments are difficult to create and support in the virtual settings made possible by ICTs [51]. Design of ICTs are generally based on implicit assumptions consistent with models of rational decision making and the transfer of explicit knowledge [59]. This makes the communication of tacit knowledge through narrative form and demonstration even more difficult [28, 51]. Such an environment may limit the absorptive capacity and growth and maintenance of the personal identity of the agents involved, resulting in an additional barrier to communicating and utilizing the tacit knowledge that is such an important component of collaborative activities [59].

These difficulties are especially relevant in the case of telemedicine. Telemedicine, "the use of electronic information and communications technologies to provide and support health care when distance separates the participants" [22, p. 2], involves collaborative activities in virtual settings [42] where two or more geographically separated health-care providers work together via IT to provide value-added health-care delivery. Health-care delivery is fundamentally a collaborative process [21, 22, 36] having both explicit and tacit knowledge aspects, where health-care providers work together to achieve outcomes in terms of access, quality, and cost that they would find difficult if not impractical to accomplish on their own. Telemedicine has the potential to increase the access to and the quality of health-care delivery while simultaneously lowering costs [13, 15, 22, 37]. Yet the utilization rates of installed telemedicine projects have been disappointingly low [36], and despite the major advances in both the capability and affordability of technology, they remain low [4, 38].

The purpose of this research is to better understand collaborative activities in virtual settings by examining them from a knowledge management perspective. Knowledge management projects are organizational efforts to leverage their knowledge assets [1, 7]. A knowledge management perspective highlights the knowledge aspects involved in collaborative activities. It provides insights into how collaborative activities enable two or more parties to achieve outcomes that would be difficult or impossible to realize by working alone. It emphasizes the communication and application of the relevant specialized knowledge to the situation at hand. This research focuses on three aspects of knowledge management—knowledge transfer, knowledge discovery, and knowledge creation—that represent the bulk of collaborative activities in

virtual settings. Such activities are examined in the context of three types of telemedicine projects—teleconsultations, distance learning, and teleradiology.

This research draws on multiple case studies of ten telemedicine projects, relying on semistructured interviews of key informants, to provide the thick description [8, 12] necessary to research the emergent phenomenon of collaborative activities in virtual settings [11, 50, 60]. It provides a perspective on how to distinguish telemedicine projects not only by the type of telemedicine activity in which they engage but the type of collaborative activities in which they are involved as well. The findings indicate that teleconsultation and distance learning projects that involve primarily the transfer of explicit knowledge are not perceived as having a positive impact on remote site health-care delivery, whereas those projects principally engaging in the creation or discovery of tacit knowledge are perceived as having a positive impact.

The study attempts to understand if an association exists between the types of collaborative activities engaged in virtual settings and the impact such projects are perceived as having. The more complex, confusing, and often paradoxical problems faced in today's environment are unlikely to be addressed by the application of explicit knowledge alone. This research contributes to a better understanding of how, in virtual settings, the tacit knowledge needed in such situations can be communicated and combined with the explicit knowledge available, making it relevant to virtual collaborative projects in other industries. Globalization is increasing the occurrence of and need for collaborative activities in virtual settings, and the findings generated here are likely to be applicable in those industries. This research is potentially applicable to most knowledge-based industries that are increasingly engaging in collaborative activities in virtual settings in order to quickly and effectively assemble and apply varied knowledge to the situation at hand.

Collaborative Activities in Virtual Settings

KNOWLEDGE IS A STOCK OF EXPERTISE—specialized, ordered information and experience that can be applied [49]—and may be either explicit or tacit. Explicit or articulated knowledge [33] is the knowing-what, consisting of facts and processes that are more readily codified, captured, and communicated. Tacit knowledge is the knowing-how that is highly cognitive and deeply rooted in both action and context [34, 43]. It resides primarily in the heads of highly trained and skilled workers generically termed *knowledge workers* [9, 10], and its personal nature often makes it difficult or impossible to articulate and capture.

Both explicit knowledge and tacit knowledge are important in that explicit knowledge enables generalization and the application of knowledge in and across different contexts, whereas tacit knowledge enables the customization of the explicit knowledge to local circumstances. Explicit knowledge without tacit knowledge is less likely to be useful for a particular situation; likewise, tacit knowledge without explicit knowledge is often of limited use [57].

The value of knowledge is in its timely application, which means that the relevant knowledge must be available in an understandable and usable form to those in need.

While the reuse of explicit knowledge presents its own challenges in terms of indexing, completeness, and quality control [27], making tacit knowledge readily accessible is perceived as being even more problematic [14, 52]. Tacit knowledge is communicated by narrative, which requires the use of metaphors and analogies, or demonstration, through the process of observation and apprenticeship [34, 35]. The communication of tacit knowledge is thought to require close personal contact, where a supportive social environment facilitates a sense of copresence and shared experiences [44, 51, 52].

Collaborative Activities

Collaborative activities enable the application of knowledge because they can be an efficient and effective means by which knowledge can be made more readily available in an understandable form. Collaborative activities involve two or more individuals working together to achieve the desired objectives that are difficult or impossible for the parties to realize on their own. Such processes generally involve the collaborating parties interacting with each other, providing the close personal contact needed for tacit knowledge communication. Collaborative activities involve continuous learning processes by which knowledge workers increase both the breadth and depth of their expertise, depending on the absorptive capacity of the individuals involved. The resulting growth in their knowledge bases enables them to handle new, even more complex situations [6, 47]. Effective collaboration efforts result in improved decision making that adds value relative to the alternatives. Collaboration is not necessary if one can accomplish one's goals by oneself; therefore, the measure for collaboration is whether it added value in terms of the outcome relative to what would have been done without collaboration [17, 47].

Insights into how collaborative activities enable the parties to achieve their desired objectives can be made by applying a knowledge management perspective. Knowledge management involves efforts by organizations to improve their performance by leveraging their knowledge assets [1, 7]. Knowledge assets are leveraged when they are used, and the focus of collaborative activities is not the articulation and capture of knowledge, but the facilitation of the application of such knowledge by its efficient and effective communication in a usable form to the party in need [54, 56]. Viewed from a knowledge management perspective, the value of collaborative activities results from the communication, integration, and application of both the explicit and tacit knowledge needed to address the situation at hand.

Such communication, customization, integration, and application occur through collaborative activities. These activities involve some combination of *knowledge transfer, knowledge discovery,* and *knowledge creation.* Knowledge transfer is any action that can contribute to disclosure, dissemination, transmission, and communication of knowledge [26, 46]. Knowledge discovery is the search for new understanding through the integration of preexisting knowledge or information. Knowledge discovery involves the noticing of previously unseen connections among items, resulting in perceiving the situation at hand in a new context, which may present new opportunities

or options [57]. Knowledge creation is defined as the development of new knowledge. By modifying, transforming, and constantly changing representations, people rearrange and reorder what they know, thus creating new distinctions and therefore new knowledge. Knowledge creation and discovery often occurs through narratives and demonstrations, and is a process of translation as well as diffusion [54, 55, 57].

Collaborative activities have both a personal and collective component. They are personal in that they are dependent on the knowledge, experiences, and absorptive capacity of the individuals involved. Their application has a collective component in that they are interpreted, converted, and applied through the interactions of individuals in a situated context. As a result, collaborative activities viewed from a knowledge management perspective involve the management not only of data, information, and knowledge, but of the social context as well [18, 31]. Collaborative activities therefore provide the link between explicit and tacit knowledge, individual and collective knowledge, and action—where collaborative activities involving the transfer, discovery, or creation of knowledge are an important means by which to communicate, integrate, and ultimately apply the tacit and explicit knowledge needed [2, 53, 57].

ICTs and Virtual Settings

Advances in ICTs have made possible collaborative activities in virtual settings, where IT is the primary means of connection. The adoption of ICTs presents a major opportunity because they have significantly expanded the knowledge network available by overcoming geographical boundaries. This results in collaborative activities having increased access to even more specialized knowledge more rapidly and at an even lower cost.

Yet the adoption of ICTs also presents major challenges to engaging in effective collaborative activities, such that attempting collaborative activities in virtual settings is even more problematic than attempting them in collocated settings [14, 51]. ICTs are more suited to the transfer of highly codified, standardized knowledge and less appropriate for the transfer of tacit knowledge. ICTs facilitate the exchange of data and explicit knowledge transfer. However, the design of ICTs is often influenced by implicit assumptions consistent with models of rational decision making [51, 59]. The implication is that ICTs generally do not effectively support the use of stories and narratives through which tacit knowledge is often communicated and absorbed, and nor does it facilitate communicating emotions, intuition, and context that are a crucial part of such narratives [28, 44, 51].

Collaborative activities are social processes in that they involve two or more individuals interacting. The tacit knowledge component requires rich and supportive social environments; however, ICTs limit the creation of shared social and cultural understanding and the amount of socialization that can occur [28, 51]. The development of trust that is an important prerequisite for collaborative activities is difficult in virtual settings [23, 40]. In addition, the environment created by ICTs is unsupportive of the creation and maintenance of the personal identity component of collaborative

activities, and virtual settings may limit the absorptive capacity of the individuals involved [59].

Yet the trend toward engaging in collaborative activities in virtual settings is only likely to continue to gain strength [2, 51]. Globalization means that collaborative activities in virtual settings are occurring on a regular and increasing basis. The ability of collaborative activities in virtual settings to potentially increase the knowledge resources available to organizations is so compelling that both the demand and occurrence of such activities in virtual settings are likely to increase.

Telemedicine: Collaborative Activities in Virtual Settings

The potential benefits of and challenges to collaborative activities in virtual settings are in full force in the case of telemedicine. Telemedicine involves collaborative activities in virtual settings. Health-care delivery is fundamentally a collaborative process where the building of a collective capacity greater than that of individuals acting independently enables health-care providers to simultaneously cope with an ever expanding medical knowledge base in the context of increased complexity in the diagnosis and treatment of patient health problems under increasing cost and time constraints. Health-care delivery has both explicit and tacit knowledge aspects. In health care, explicit knowledge is the scientific basis of medical knowledge that has been published and widely accepted. It is based on clinical studies (controlled experiments demonstrating the efficacy and safety of treatments for specific pathologies), clinical practice guidelines (recommended protocols for the treatment of various health conditions), and epidemiological studies of risk factors for disease. Health care also involves considerable amounts of tacit knowledge that is difficult to test scientifically or articulate. This is exhibited in the subjective or intangible nature of health care, which is often referred to as the "art of care" [48].

The three standard measures of health-care delivery outcomes are access, quality, and cost [21, 22], and telemedicine has the potential to increase the access to and the quality of health-care delivery while simultaneously lowering costs. From a knowledge management perspective, the value of collaborative activities results from the communication, integration, and application of both the explicit and tacit knowledge needed to address the situation at hand. The measure for collaboration is whether it added value in terms of the outcome relative to what would have been done without collaboration [17, 47]. Consistent with this concept, the measures for the effect telemedicine has on remote site health-care delivery is the difference between remote site health-care delivery prior to the introduction of telemedicine and the extent to which access to and quality of health care available is increased, and the change in the cost of delivering such care.

This research focuses on three of the most commonly deployed [22, 37] types of telemedicine projects. *Teleevaluations* [22] are the reading or interpretation of patient information by another knowledge worker. They almost always involve knowledge transfer. Examples of teleevaluations include teleradiology, teledermatology, and telepathology. *Teleradiology,* the sole type of teleevaluation studied in this research,

involves digitized radiographic images being sent to a radiologist who reads the images and provides a diagnosis by e-mail or telephone, depending on the urgency of the situation.

Distance learning in health care [22] includes activities such as continuing medical education (CME) credits, graduate and undergraduate courses, and public health seminars. Depending on the subject matter, the class type, and the audience, education can involve knowledge transfer or knowledge discovery. Larger and more structured educational experiences, such as undergraduate courses, tend to involve knowledge transfer, where the professor or health-care professional transfers part of his or her expertise to the students. Smaller and less-structured educational experiences, such as seminars and some CMEs, involve knowledge discovery, where students or health-care professionals gain a new understanding from previously gained knowledge or information.

Teleconsultations [22] generally involve one health-care provider (usually a primary care provider) seeking advice from another (usually a specialist or subspecialist) who has specialized expertise regarding the health problem at hand. Such consultations may be knowledge transferring, discovering, or creating, depending on the situation. Knowledge transferring consultations involve one care provider giving his or her opinion of a patient's illness based on the care provider's specialized expertise. Knowledge discovering consultations are those consultations that, for example, result in the discovery of a new diagnosis based on a new interpretation of the available information. Knowledge creating consultations are the rarest. An example of one is the creation of a new treatment protocol for an illness or disease—that is, the combination of different therapeutic drugs.

Methodology

Research Design

MULTIPLE CASE STUDIES, RELYING ON FACE-TO-FACE semistructured interviews of key informants, were used in this research in order to provide the thick description [8, 12] required to understand and explain the emerging phenomenon of collaborative activities in virtual settings. Validity and generalizability were also enhanced through the replication of results using multiple cases [3, 25, 50, 60].

Sample

Three telemedicine networks located in the United States and involving at least three telemedicine projects were studied. Each of the networks had at its hub a university-affiliated health sciences center (HSC), and the spokes of the networks were located in relatively isolated rural areas. HSCs were selected because the vast majority of telemedicine projects involve university-affiliated health sciences (or medical) centers [22, 36] that were charged with providing health care to remote areas. The telemedicine projects studied were part of the normal practice of medicine either as revenue-generating or cost-reducing projects. Ten telemedicine projects involving

five teleconsultation, three distance learning, and two teleradiology telemedicine activities were examined.

Theoretical (or purposeful) sampling was utilized in an effort to address potential threats to the external validity and construct validity of this research [50]. HSCs were selected because they and their telemedicine project partners tended to have certain characteristics that naturally accounted for alternative explanations for the impact, or the lack thereof, of installed telemedicine projects [41]. For example, all the HSCs had a mission to improve health care for their respective rural populations, and all the specialists were paid a salary by the state. Therefore, the lack of specialist reimbursement was less likely to be an inhibiting factor in the short run. All of the telemedicine projects studied were intrastate, eliminating potential interstate physician licensing barriers. Malpractice liability insurance concerns were less of an issue because all the specialists were engaged in HSC-sanctioned telemedicine projects; therefore, their activities were covered by their respective facility's umbrella liability coverage. High start-up and operating costs were not inhibitors because almost all the projects in this research received external funding.

Site selection was based on four criteria. First, each site had to have at least three active telemedicine projects. Second, each site had to have one of each of the three types of telemedicine activities—teleconsultation, distance learning, and teleradiology. These two criteria enabled both within and between network comparisons of different telemedicine projects. Third, the sites could not involve military or correction facilities because the voluntariness of participation and the social dynamics in such situations may be different from those in civilian projects. Fourth, each site had to have been operational for a minimum of six months to allow the inevitable technological and procedural bugs to be addressed and to allow the novelty of telemedicine to pass.[1]

The World Wide Web was searched to find sites that met these criteria. The second criterion—different types of telemedicine activities within each project—was discarded because sites meeting this criterion could not be found. Although a number of potential sites claimed to have all three types of telemedicine activities operational at the time of this study, only one actually did. Indeed, a number of potential sites that claimed on their Web pages to have active telemedicine projects did not have any active telemedicine projects at the time of this study. This exaggeration of the state of active telemedicine projects was not uncommon. The Office of Rural Health Policy [36] found that approximately 25 percent of the hospitals they surveyed that claimed to have at least one active telemedicine project in fact had no operational telemedicine projects. Each site selected included at least one teleconsultation project, which enabled teleconsultation activities to be compared across the telemedicine networks. Both distance learning and teleradiology projects occurred at two sites, enabling at least one between network comparison for these telemedicine activities.

Data Collection

Face-to-face, issue-focused, semistructured interviews of key informants provided thick and richly textured data [39, 45] and eliminated the problem of item nonresponse, which plagued earlier telemedicine studies [36]. Seventy-four health-care professionals

were interviewed, and the interviews were audiotaped and transcribed. Key informants were members of one of three groups—clinicians (physicians, physician assistants, nurse practitioners, or medical residents/students), administrators, and IT professionals. They were selected based on current or past direct involvement in their organization's telemedicine project. Table 1 presents a summary of the key informants by position and location. The interviews were approximately equally split between those conducted at the HSCs and the remote sites, and the number of interviews per HSC was proportional to the number of telemedicine projects they had active. Further, the proportion of key informants who were clinicians, administrators, and IT professionals was fairly evenly distributed across the sites.

Construct validity and reliability were enhanced by triangulated data collection [11, 60]. This was achieved by interviewing multiple key informants and collecting multiple types of data. Different perspectives of telemedicine projects were obtained by interviewing multiple key informants from the three different functional groups at both the local health-care facility and the HSC involved in each telemedicine project studied. Teleconsultations or videotapes of teleconsultations were observed when possible, and documentation such as grant proposals/follow-up, needs assessments, and strategic plans were collected when available. Triangulated data collection resulted in a richer understanding of the telemedicine projects and helped address both key informant and researcher bias issues [16].

Data Analysis

The transcribed interviews were analyzed and coded. The coding scheme was theoretically based [30], where quotations were categorized according to the constructs of interest. The explicit specification of the constructs of interest provided the structure by which to engage in constant comparative analysis both within and between cases. Internal validity was enhanced through pattern matching [50, 60], and the use of computer-assisted qualitative data analysis software (CAQDA) enabled more structured and reliable pattern matching both within and between cases [24, 32]. CAQDA's coding and retrieval functions were utilized in a manner that made possible both more reliable coding of the qualitative data and more frequent and more in-depth comparative analysis.

Key informant interviews established the need for the telemedicine projects and eliminated alternative explanations such as technology problems for the failure of a telemedicine project. They were also used to assess the type of collaborative activity and the impact the telemedicine project had on the cost, quality of, and access to remote site health care. Note that the coding examples presented in the Results section usually involves only one key informant. In most cases (including those presented), multiple confirming comments from different key informants involved in that particular telemedicine project, as well as other forms of evidence, were used to determine the coding value.

The three standard measure of health-care delivery—access, quality, and cost [21, 22]—were the basis of measuring the impact the telemedicine projects had on remote site health-care delivery. Access is the timely use of personal health services to achieve

Table 1. Key Informants by Site and Position

	Site W					Site X						Site Y					Grand
Position	HSC	WA	WB	WC	Total	HSC	XA	XB	XC	XD*	Total	HSC	YA	YB	YC	Total	total
Administrator	4	1	1	1	7	4	1	1	1	0	7	3	1	1	0	5	19
IT professional	4	1	2	0	7	3	3	1	0	0	7	3	1	3	0	7	21
Health-care professional	5	2	1	2	10	8	0	3	2	1	14	5	2	2	1	10	34
Total	13	4	4	3	24	15	4	5	3	1	28	11	4	6	1	22	74

* WD key informants also included WA administrator and IT professionals.

the best possible health outcomes [20]. Quality is the degree to which health-care services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge [19]. The impact on cost is relative to the cost of similar episodes of medical care prior to the start of the telemedicine project and therefore excluded both the operating and capital costs of the telemedicine equipment. The impact was determined by the change in these measures resulting from the collaborative activities in telemedicine projects as compared to the access, quality, and cost of health delivery in the remote areas prior to the advent of telemedicine. This impact measure is consistent with the conceptualization of the outcome of collaboration being the value-added decision making as exhibited by the difference between the outcomes the parties could have achieved on their own relative to what would have been done without such collaborative activities [17, 47].

Telemedicine's impact on remote site health-care delivery was measured as the *perceived* change relative to the conditions prior to the advent of telemedicine. This measure was used because legal issues prevented the researcher from having access to patient records, and most telemedicine sites tended not to maintain such records [36]. Each of the three measures of impact were judged on a seven-point Likert scale, with seven meaning a telemedicine project's impact in terms of the particular type of impact was very positive, and one meaning the impact was very negative. The researcher's coding of the three impact variables for each telemedicine project was assessed by an information systems professor, who concurred with the researcher's coding 86.7 percent of the time.[2] The coding of the impact variables were also reviewed and approved by three other information systems professors.

Table 2 presents a summary of the impact values of each telemedicine project. The original research conceptualization anticipated analyzing the association between the different types of knowledge activities and how they were perceived as affecting the access, cost, and quality of health-care delivery in the remote areas. However, the impact values for each site—access, cost, and quality—were highly correlated and analyzing each impact type separately was unlikely to provide additional meaningful information or insights. Therefore, the three impact types were summed for each project, and only this one figure, *the overall impact on health-care delivery,* was used in the data analysis. The maximum score possible for impact was 21 points and the minimum possible score was three points. In this research, the highest score was 21, and the lowest score was 11. The impact measure was unbalanced in that its values could be positive but, from a practical standpoint, could not be negative, because it was difficult for telemedicine projects to negatively impact either access to or quality of remote site health-care delivery.

Table 3 presents an overview of the ten telemedicine projects in terms of their duration, telemedicine activities, virtual team composition, primary collaborative activity, IT configuration, and impact on remote site health-care delivery. The telemedicine activity was categorized as either teleconsultation, distance learning, or teleradiology, and the primary collaborative activity was coded as either knowledge creation, knowledge discovery, or knowledge transfer. While it was not uncommon for a telemedicine project to involve a combination of knowledge transfer, knowledge discovery, and

Table 2. Impact Values by Telemedicine Project

	WA	WB	WC	XA	XB	XC	XD	YA	YB	YC
Access	5	7	6	4	4	7	7	5	7	4
Quality	5	7	6	4	4	7	7	7	7	4
Cost	2	7	7	3	4	7	7	4	7	4
Overall	12	21	19	11	12	21	21	16	21	12

knowledge creation, in each case, one of these types of collaborative activities was the dominant type. Therefore, the activity coded for each telemedicine project was the primary knowledge activity in which the telemedicine project engaged. The coding of the primary collaborative activity variable was reviewed and approved by three information systems professors.

Each of the telemedicine projects utilized one of three IT configurations. *Still image transfer* involves the ability to transfer asynchronously graphical files such as digitized X-rays from one location to another. *Videoconferencing* is the ability to transfer real-time audio and video from one location to another, enabling parties at both locations to see and interact with the other parties. *Multimedia* includes videoconferencing capabilities, the real-time transfer, viewing, and manipulation of data files, and a high-powered light source to which medical devices can be attached, enabling both parties to see a patient's ears, nose, and throat. It may also include an electronic stethoscope, which enables both parties to hear the patient's heartbeat and breathing.

Results

IN ADDITION TO AN OVERVIEW OF THE PROJECTS, Table 3 presents a summary of the findings. Six of the ten telemedicine projects were perceived as having a positive impact on remote site health-care delivery. Some interesting patterns emerged in the case of the distance learning and teleconsultation projects. The findings indicated a strong association between the primary collaborative activity and the type of telemedicine activity in which the telemedicine projects engaged, and the impact such projects were perceived as having on remote site health-care delivery. Distance learning and teleconsultation projects that primarily involved knowledge transfer uniformly were *not* perceived as having a positive impact. In other words, distance learning projects had to principally involve knowledge discovery, and teleconsultation projects had to primarily involve either knowledge discovery or knowledge creation in order to have a positive impact on remote site health-care delivery.

Teleradiology

The two teleradiology projects were very similar in the primary type of collaborative activities in which they engaged. Both teleradiology projects had undergone at least a four-month trial period during which the transmitted image quality was deemed to be an adequate basis for making a diagnosis. Teleradiology project YA was perceived as

Table 3. Telemedicine Projects Summary

HSC	Telemedicine project (duration)	Telemedicine activity	Team composition and patient involvement[1]	Primary collaborative activity	IT configuration	Impact (value)[2]
W	WA (2 years)	Teleradiology	Radiologist *Attending primary care physician*	Knowledge transfer	Still image transfer	No impact (12)
	WB (1 year)	Distance learning—rural residency	Supervising physician and rotating specialists, patient (sometimes) *Residents and supervising physicians, patient (sometimes)*	Knowledge discovery	Video-conference	Very positive (21)
	WC (9 months)	Teleconsultation—oncology	Oncologists, nurses, psychologist, administration *Oncologist, patient, and family (always)*	Knowledge discovery	Video-conference	Very positive (19)
X	XA[3] (4 months)	Teleconsultation—pediatric oncology	Pediatric oncologists *Nurse, patient, and parents (always)*	Knowledge transfer	Multimedia	No impact (11)
	XB (1 year)	Distance learning—medical student clerkship	Supervising physician and rotating specialists, patient (rarely) *Medical students*	Knowledge transfer	Video-conference	No impact (12)
	XC (9 months)	Distance learning—podiatry residency	Supervising physician and residents, patient (sometimes) *Residents, supervising physician, and area podiatrists, patient (sometimes)*	Knowledge discovery	Video-conference	Very positive (21)
	XD (1.5 years)	Teleconsultation—infectious diseases	Infectious diseases specialist and other specialists (rarely) *Primary case physician*	Knowledge creation	Multimedia	Very positive (21)

(continues)

Table 3. Continued

HSC	Telemedicine project (duration)	Telemedicine activity	Team composition and patient involvement[1]	Primary collaborative activity	IT configuration	Impact (value)[2]
Y	YA (1 year)	Teleradiology	Radiologist *Attending primary care physician*	Knowledge transfer	Still image transfer	Positive (16)
	YB (8 years)	Teleconsultation—multiple specialties	Different specialists, telemedicine administrator *Primary care physician, patient (sometimes)*	Knowledge discovery	Multimedia	Very positive (21)
	YC (5 years)	Teleconsultation—multiple specialties	Different specialists, telemedicine administrator *Physician assistant, patient (sometimes)*	Knowledge transfer	Multimedia	No impact (12)

Notes: [1] HSC team members in the telemedicine sessions are presented in roman type. Remote site team members and patient involvement in the telemedicine sessions are presented in italics. [2] The number in parentheses is the overall impact the project had on remote site health-care delivery. [3] Project was discontinued by the pediatric oncologists.

having a positive impact on remote site health care, while project WA was not. The difference, discussed later, was the social context in which they existed.

Teleradiology tended to be consistent with the traditional conceptualizations of knowledge management in virtual settings in that it primarily consisted of knowledge transfer activities, where the expert (the radiologist) would apply his or her knowledge and expertise, and then explicitly transfer such knowledge by reading the radiographic image and providing a diagnosis. The chairperson of the department of radiology at HSC Y stated:

> HSC Y Radiologist: They [the rural sites] don't have access to expertise—the guy who is going out there is a low-level general radiologist. We have real experts, real experts in pediatrics, neuroradiology. You know, the subspecialty areas of radiology I can cover for [remote sites]. Why? So they don't have to hire a pediatric radiologist. There's not enough volume. . . . They have a general radiologist but [he] still deals with neurosurgeons. They don't need a general radiologist—they need a neuroradiologist and the pediatric surgeon needs the consult with the pediatric radiologist.

Occasionally, teleradiology would consist of some knowledge discovery activities. In such cases, the HSC radiologist would telephone the remote site physician after receiving the digitized images to both get more information that was not on the radiographic image and discuss other relevant characteristics of the patient, and they would interact in order to determine the diagnosis. As a primary care physician at site WA commented:

> Interviewer: When you send up a radiology image, how is a reading reported?
>
> WA Physician: The radiologist will call us back and ask questions. We will give him as much clinical information as we can. Especially if they have a question. They may call and say, "This is what I'm seeing. What are you seeing?" They want a clinical picture so they can help us more.

The primary difference between the two projects was the social context in which they occurred, particularly in the trust conditions within and between the collaborative parties. Teleradiology project WA was not perceived as having a positive impact on remote site health-care delivery because the lack of trust between the remote site physicians and the HSC radiologists, and between the remote site physicians themselves. The information systems professionals at HSC W, who initially had traveled to site WA on a weekly basis, described WA's remote site physicians as "a bunch of cowboys." They added:

> HSC W IS Professional 1: It was an unusual group. We decided that was a barrier that would limit the creation of a beneficial program with them. If we couldn't get the physicians to work together very well, to share resources and learn from each other from the telemedicine relationship . . .
>
> HSC W IS Professional 2: If they don't trust and rely on each other, why would they trust and rely on us?

Distance Learning

Three distance learning projects were studied. Distance learning projects that principally involved knowledge discovery had a positive impact on remote site health-care delivery, while those distance learning projects involving primarily knowledge transfer did not. Distance learning rural primary care residency project WB involved HSC specialists and residents receiving specialized training in rural health care at a regional medical center primarily engaging in knowledge discovery activities where the patients were sometimes present during the sessions. It was deemed as having a positive impact on remote site health-care delivery, while distance learning medical clerkship project XB, involving HSC specialists and third-year medical students at a primary care clinic mainly engaging in knowledge transfer activities without patients present during the sessions, was not. Distance learning rural project XC involved HSC specialists and a podiatry residency rotation for the HSC's first-year podiatry residents at a group of three federally funded health clinics and the local state hospital mostly engaging in knowledge discovery activities where the patients were sometimes present during the sessions. Project XC was perceived as having a very positive impact on remote site health-care delivery.

There was a strong, philosophical difference between the distance learning projects that had a positive impact on remote site health-care delivery and those that did not. The distance learning projects that had a positive impact focused on empowering the remote site care providers and fostering a sense of independence. These projects tended to consist of the discovery of tacit knowledge (with explicit knowledge transfer as needed). A specialist at site W involved in the distance learning project with WB commented:

> HSC W Physician: Whenever I talk with somebody about telemedicine, I have to point out that my view of it is a little bit different than a radiologist's view of it—the radiologist or cardiologist or whoever; their view is to bring the wisdom of the Mecca to the unwashed in the rural area. My concept of it is to support people in their skill development and make them independent. It's a little bit different in approach. Their thing is to foster dependency; mine is to create independence because I think that people can learn to do things, and that will make them better providers and more—give them and encourage them to get skills so that they don't need to call up all the time.

In contrast, medical student clerkship distance learning program XB was perceived as not having a positive impact because the HSC tried to improve collaboration by exerting more control over the remote site. Instead of a partnership, there was an implied hierarchy where the HSC had the knowledge and wanted to transfer it to the remote site—which was assumed to need it. A physician at site X involved with medical student clerkship program XB commented:

> HSC X Physician: They [XB] are affiliated with [X] but they're kind of independent programs that have a link, an affiliation with us, so they each run themselves. But to be able to improve collaboration and communication between

> the programs is the goal. In that way, we are probably trying to influence some control from the Health Sciences Center to these affiliated residency programs.

This implied philosophical difference had significant implications in terms of what was involved in the telemedicine sessions. The distance learning programs having a positive impact were designed to complement the existing knowledge possessed by those at the remote sites by engaging in collaborative activities that predominantly involved the discovery of tacit knowledge. This was achieved through discussing actual patient cases. A remote site podiatrist at XC who attended the sessions commented:

> Interviewer: Is it [the session] primarily lecture [format] or is it interactive?
>
> XC Physician: It [the session] is very interactive, very. There are questions shot back and forth, the ideas are flowing. We see what they're doing, they see us—what we've got—and we actually present cases from down here too to them.

The head of site X's podiatry school described the session activities and how they tried to get the remote site involved by making the sessions a collaborative effort:

> HSC X Physician: We bring patients sometimes for rounds and [XC] have too, so if they have complicated cases, they have brought in a few. One part about our round is that we like for [XC] to present at least one case during the rounds so that they'll have the opportunity to present one of their patients for discussion if they want our input and thoughts and ideas on that particular case. So we try to incorporate that with that participant—not just on a receiving end on what we do here—to make it truly a collaborative effort.

A physician involved with the rural residency distance learning project concurred that the value of the distance learning sessions was interacting with the specialists:

> WB Physician: I think that the time we can go over these cases, it helps clarify for the people involved what happened with the patient. And the more you understand and things make sense, then the more you can make logical decisions about their treatment. So any time you have a conference where you are discussing patient care and having multiple person's input—I mean we do that all the time in the medical setting, and having telemedicine—now you can take experts in [city], that aren't here, and can get their information.

In contrast, medical student clerkship distance learning project XB was not viewed as being effective or useful because the sessions primarily involved the transfer of explicit knowledge. A medical student at site XB lamented over the use of lectures during the distance learning sessions and how he viewed the idea of interactive sessions involving actual cases as being more interesting and having more value:

> XB Student: It's all lectures for students. There is no consultations or anything like that. It would be a lot more helpful for that—like if you want to talk to some specialist in [XM], that would be a whole lot more helpful. . . . I've seen

> the teleconferences where they actually have a patient there and you can listen to their heart sounds, you can see in the otoscope, you can look at their tympanic membranes, that's really neat but we're all—we're doing something completely different here. It's all lectures.

The specialists at site X involved with telemedicine project XB realized that more interactive cases would be better and tried to present them. However, in the execution, these physicians tended to focus more on the transfer of explicit knowledge such that, instead of discussing the cases, the distance learning sessions reverted to a lecture format.

> HSC X Physician: They're mostly cases, but some of them still lecture and it works better if it's completely a case conference but some of the content doesn't lend itself too well. They (the presenting physicians) need to give background before they go into cases. So they spend sometimes an hour doing background and then half an hour on cases. It would be better if it were twenty minutes on background and an hour and twenty minutes on cases.

In contrast, rural residency distance learning project WB managed to find a balance between lecture and the transfer of explicit knowledge, and a more interactive process involving the discovery and integration of tacit knowledge. A remote site physician at WB commented on the format and content of a high-risk obstetrics distance learning session:

> WB Physician: They go over cases that they work with . . . [and we] present some of our more interesting cases. He [HSC W Physician] often does a didactic where he presents an article, does some topic. So we try to get the residents in OB [here] and a couple of other faculty online.
>
> Interviewer: Do these sessions usually involve cases that have already happened, or do they involve live cases?
>
> WB Physician: It's usually a combination. It is more—there are patients who are still pregnant and we are still involved in the management of their care. Usually it is decisions we have already made, and we are getting their point of view. Would they have done anything different or would they do anything different at this point? I find it really helpful to get that perspective. Some of the things that are done here are different than what I am used to. So it is kind of nice to hear "yeah, we would probably do something different." Not that it is really a big deal in terms of patient management. It is more just kind of—there are different ways of doing things, and getting a different perspective can be helpful.

Distance learning sessions involving primarily the discovery and integration of tacit knowledge worked because they were more engaging and involved a truly collaborative effort. Such activities added value much more than just the transferring of explicit knowledge. The head of the rural residency program at WB described why he felt such sessions were better:

> WB Physician: I can't read a book on nutrition, health, and disease for any amount of time. I can't read that. But if you are given a patient with that, then it becomes a whole lot clearer. So, I think your question—say there is an OB/GYN lecture being done in [WM]. So, you say, "Well I have this patient, what would you do with this kind of patient?" It really concretely brings to me and it sort of settles in my psyche a whole lot easier if I have a patient to relate to.

Teleconsultations

Five teleconsultation projects were studied. The three teleconsultation projects chiefly involving knowledge creation or knowledge discovery were perceived as having a positive impact on remote site health-care delivery, whereas those focusing primarily on knowledge transfer were not. Teleconsultation projects YB and YC involved multiple specialties where the patient and his or her family were usually present during the sessions. YB involved primary care physicians at a rural hospital mainly engaging in knowledge discovery activities. It was perceived as having a positive impact on remote site health care, while project YC, which involved a physician assistant at a rural health clinic primarily engaging in knowledge transfer activities, was not. Infectious diseases teleconsultation project XD consisted of HSC specialists and a rural hospital's primary care physicians engaging principally in knowledge creation activities with patients usually not present. It was perceived as having a positive impact on remote site health care, whereas pediatric oncology teleconsultation project XA, involving pediatric oncologists at the HSC and nurses mainly engaging in knowledge transfer activities with patients and their parents present during the sessions, was not. Bone marrow transplant teleconsultation WC involved HSC transplant specialists, nurses, psychologists, and administrative staff, and two rural oncologists at a private clinic with the patient and his or her family almost always present during the sessions. It was seen as having a positive impact on remote site health-care delivery. This teleconsultation project involved primarily knowledge discovery activities and was utilized for initial consultations to determine if the patient was a viable candidate physically for a transplant and psychologically for the extended stay in isolation the transplant entailed, and whether the patient wanted to undergo a high mortality treatment for a life-threatening disease with these particular specialists. It was also used for follow-up after the patients had returned home.

The teleconsultation projects that had a positive impact on remote site health-care delivery had many similar characteristics. They all tended to focus on the "art" of medicine and assist the remote care providers in making sense of complex, ambiguous decision problems.

> HSC X Physician: Yeah, they always say it's an art based on a science, but most of it is an art. I mean, well, that's an old story, but people like to think that doctors deal with real concrete issues that are real black and white, and the vast majority of the time, we don't know 100 percent what is going on and the vast majority of the time, we're dealing with gray issues, not black and white.

That is, a major aspect of the successful teleconsultation projects was that they primarily involved the discovery (or sometimes the creation) of tacit knowledge. The director of the bone marrow transplant department at site W explained the importance of the tacit dimension and why he decided to go ahead with teleconsultation project WC:

> HSC W Physician: It was clear to me that by far and away, the most important part was the discussion with the patient. Most of the history would have come on paper. I'm going to ask a few questions, but they are questions that the patient could have answered as well as the doctor. . . . The X-rays and the laboratory data, I could review just as well prior to the discussion, or it could be faxed to me or it could be sent electronically, or whatever. The physical examination is perceived to be a high-impact part of what doctors do. But, in fact, its value has declined as imaging has gone up. . . . So it struck me that we ought to do this because the critical part was the connection, the discussion with the patient, looking them in the eye, getting the pieces of information that you could not quite get off the paper.

The tacit knowledge aspect in the educational component of the teleconsultations that affected remote site health-care delivery in a positive manner was highly valued by the remote site health-care professionals because it furthered their understanding of the problem or process as a whole and enabled them to provide better care. For example, the oncologists at WC felt they now had a better appreciation of the bone marrow transplant process because they gained knowledge not found in textbooks. An oncologist at WC commented:

> WC Physician: I think that the ones [benefits] that I didn't anticipate—I think that I've had a better understanding of the high dose chemotherapy and stem cell [bone marrow] transplant procedures. In other words what is being done at the university. It's one thing reading about it in a textbook. By doing this, I felt a lot more involved and a lot more responsible for the decisions so that it's been stimulating and educational for me so I feel like I'm a lot smarter about that because I'm part of the process.

As a result, the patients (and often their families) were able to leave the HSC earlier than before. Prior to the teleconsultation project, the rural oncologist's patients who underwent the bone marrow transplant procedure were severely immunocompromised and had to spend six to ten weeks living in short-term apartments near the HSC in order to undergo blood transfusions or other types of therapy on an outpatient basis. With the advent of the teleconsultation project, these patients (and members of their family who often stayed with them at the HSC apartments) could now return home after three weeks in the hospital and receive much of their posttransplant support at the oncologists' clinic. As a result, the patients and their insurance companies were spared the cost of the short-stay apartment rental, and the teleconsultation project enabled the patient's friends or relatives to continue working on at least a part-time

basis while the patient underwent posttransplant activities at the local oncologist's office.

> WC Physician: They [the patient's family] get home. They don't have to pay for a hotel room. It's no little thing that a lot of them can still work here and keep their health insurance or whatever. So it's kind of hard to explain to people but I think most people that have a family—if I think what would happen if I had to go spend a week up in [HSC city] to my family and be away from my job. It would hit home and then these are people not even with illness. There are a lot of social and economic implications.

The primary care physicians involved in multiple drug-resistant infectious diseases teleconsultation project XD described how they needed expertise that was not readily available and how they used the teleconsultation sessions to combine their expertise with others to create the needed expertise. A remote site physician at XD commented:

> XD Physician: We have a working relationship that's very, very different now that probably would not have evolved [without the infectious diseases problems]. We have a couple of really not reluctant docs that evolved into infectious diseases—but docs that just fell into it and didn't know they were going to get into it. And it's one of those things that you don't want to admit you really don't know much about it. So you kind of read up on it a little bit and it's not something that you can just read up on it a little bit.
>
> Interviewer: Why is that?
>
> XD Physician: Because most literature on infectious diseases is from the 1950s. Actually it's good literature to go back to. It really is. Unfortunately, it's not always readily accessible. It's not normally in your library. And the nuances of treatment.

The result was that the quality of the health care delivered went up and the cost went down. The teleconsultation project at XD enabled the remote site to treat even more complicated cases of infectious diseases at a lower cost. The physician at XD noted:

> XD Physician: It's [telemedicine's] become our workhorse—especially for infectious diseases. . . . People talk about cost-effectiveness. One case of infectious diseases costs the state $250,000. Since we introduced telemedicine, we've gotten that down to less than $100,000. So you figure then—you know it's one thing when you have ten of those cases. Now when you look at 184 or 289 or 500 and it grows exponentially like that—we're going to bring it down from $100,000 to $80,000 to $50,000. We're going to try and reach the baseline (treatment cost)—the cost of the drugs only just to get these people through the (treatment) process.

In contrast, the teleconsultation projects mainly involving the transfer of explicit knowledge were not viewed as having a positive impact. A pediatric oncologist at

HSC X involved with the project at XA described the teleconsultation sessions and why they stopped having them:

> HSC X Physician: But I think after kind of an initial "gee whiz" kind of stuff and the sort of the feasibility was done, you know, it's kind of like, well, what next? And so then we went through a phase where you know it really wasn't helping us all that much in the care to examine every individual patient with telemedicine. The nurse would go over the blood counts and sort of give a kind of a report. And sometimes she would see patients that would have particular problems and then show them to the doctor, but that ended up being kind of like, well, you could do that with a fax and a telephone and, so, after that, you know, when we really didn't have anything more, I think we basically stopped using it.

This was in stark contrast to the infectious diseases teleconsultation project, where the discovery of tacit knowledge was critical. The director of medical informatics at HSC X commented about the difference between the pediatric oncology and infectious diseases teleconsultation projects:

> HSC X Physician: The important point there is that their [infectious diseases] information needs were different. . . . They needed to talk—for the [infectious diseases] consult—they don't actually have the patient there—it is physician talking to physician.

This is not to say that the transfer of explicit knowledge was not important or useful. It was, so long as the explicit knowledge could not be transferred in other ways, or it facilitated the discovery or creation of more tacit knowledge. This particularly held true in the case of visual cues. A remote site physician at YB stated:

> YB Physician: I think that the key is, where a picture is worth 1,000 words. When you can get a situation where a picture is worth 1,000 words, that's where it's most helpful, like, you know, if you're just given data and the guy can comment on the data, you know, about a patient and, then, it's really not that necessary, but you know, say you try to describe a skin lesion or something. Well, you can say maculopapular until you're blue in the face, but people don't really know what you're trying to say, but when you show them pictures, that says it all.

The same physician explained the criteria by which he chose to use the teleconsultation equipment instead of the teleradiology system (connected with another HSC not part of this study):

> YB Physician: Well, if you just want an X-ray read, I mean, if it's not a question of making a clinical therapeutic decision, if it's just a question of reading the X-ray, and if you know what you're going to do once you get the X-ray results, then there's no need to get a clinician to say something else, you just need the

> X-rays read. . . . But if there's something that requires both looking at the X-ray and looking at the patient, then usually, you would need the [teleconsultation].

He proceeded to give an example of such a situation:

> YB Physician: A guy got shot with a bunch of shrapnel. So, I presented him over the [teleconsultation equipment]. This was just a few weeks back, and I presented the X-rays, plus I presented him, because I was showing where the, you know the, I was showing his wounds. The problem was he had this shrapnel but he was on Coumadin [an anticoagulant] for a heart condition. So, you know, you don't want to dig in and get a bunch of shrapnel and have him bleed and have big hematomas and, you know, stuff like that. And so, I had gotten some of it out, but I had left some of it and I wanted another opinion from somebody saying, "It's okay to leave this here." So, in that case, I had to both show, or I felt like I needed to show, both the wounds and the X-rays.

A general theme across the teleconsultation projects that were viewed as being successful was that they helped the remote site health-care providers address complex or unusual problems that required knowledge discovery or creation activities involving a large tacit knowledge component. The head of the bone marrow transplant unit at site W commented:

> HSC W Physician: We generally reserve it [the teleconsultation sessions] for the patients who have a unique complication. If they have a problem that's not standard and the oncologists down there are not quite sure they feel comfortable managing it totally, we'll put the patient . . . we'll make a telemedicine appointment and they'll come into the office and the doctor will interview them; then we'll get on the television and we'll talk to them and discuss the management points.

This often involved the reinforcement of the remote health-care provider's assessment of the situation. A physician involved with multiple specialties teleconsultation project YB commented:

> YB Physician: You know, most of us can figure out what needs to have a procedure and which ones don't. Most of it's coming down to, you know, data management, reassurance, and that kind of thing. Very rarely do we not have any kind of idea at all of what is happening.

Interestingly, teleconsultation collaborative activities were not viewed as useful during emergencies. Emergencies can often be complex problems in that patient history, preexisting medical conditions, and the exact injury may not be known, and the more serious the injury, the more likely the patient is unable to communicate essential information. Further, the nature of emergencies is such that time is of the essence. Teleconsultations systems were not utilized much in emergencies because the problem space was redefined from being a complex problem into a structured problem where the remote site health-care providers had to decide whether to treat the patient

locally or transport them to the nearest HSC. To make that decision, the remote health-care provider had to answer two questions: First, are the facilities available locally to provide the type of treatment necessary? Second, is the expertise and experience available locally to provide the necessary treatment? If the answer to either of these two questions was no, then the decision was that the patient needed to be transported to the nearest HSC.

Although it was possible for one of the two questions to be answered maybe instead of yes or no, the reality of the situation was that the frequency of such occurrences was rare. For instance, the HSC involved with the multiple specialties teleconsultation projects experienced approximately two emergencies per year that were in that gray area and handled over the telemedicine system. The director of telemedicine commented:

> HSC Y Physician: How many emergencies do you have? That's what you publicize and you show and all that sort of stuff. . . . In the emergency room in the [rural areas] as far as I'm concerned, there has always been one decision: I keep or I send. And if they send, they shouldn't be screwing around with all this, all this consultative service and all that sort of thing. . . . Now, if I'm a surgeon out there and I have the facilities, I might decide to keep the patient, but if I'm a general practitioner with no surgical experience, or if I'm a physician assistant or a nurse practitioner—I don't care how great my facilities are, I'm going to ship. I'm going to get them out of there. And if I'm a surgeon and I don't have the facilities, I'm going to get them out of there anyway because I have nothing to work with.

However, the educational component of the teleconsultation sessions in non-emergency situations had the potential to improve the decision-making quality of the remote health-care providers in determining whether to treat an emergency locally or to send it to the HSC. This depended on the previous training and absorptive capacity of the remote health-care providers. The director of telemedicine stated:

> HSC Y Physician: I think you could do a lot of training to recognize to ship or to hold. I don't think you could do a lot of training other than going back to the residency to hold a heck of a lot higher percentage. In other words, if I'm a physician's assistant or I'm a general practitioner, you can train me to make much better decisions to keep or hold and not make mistakes—narrow down that gray zone. But it would be damn hard for you to teach me to be a surgeon to keep a heck of a lot there.

The educational component of the teleconsultation sessions could, in some situations, expand the competencies of certain remote site health-care providers and enable them to handle more complex emergencies locally:

> HSC Y Physician: It all depends on the training of the, some GPs [general practitioners] out there have good surgical training. You see, you maximize that, but if you start from scratch, it's dangerous because they have all different

> qualities. So the key is to be selective. For instance, we have Dr. [name] down in [XB]. The guy wanted to be a surgeon, so he took a year of surgery or something like that. He's a pretty damn sharp surgeon. This guy can teach him to do an endoscope with no problem. I don't think you could ever teach [general practitioner] because he's an internist. He won't touch a knife. So a lot has to do with the type of individual you have and it varies very greatly. Will it maximize the abilities and training of the periphery? . . . You would still have to send back 15–20 percent because those are the oddball things that only a specialist is seeing. You [the remote physician] don't do that everyday; you see, he [the specialist] does.

Like the teleradiology projects, the impact of the teleconsultation projects was affected by the social context in which they occurred. The successful teleconsultation projects occurred in a supportive social context that facilitated collaborative activities. This included treating the remote health-care providers with respect. Traditionally, subspecialists and specialists had the highest status within the medical profession, and primary care providers—particularly rural or remotely located primary care providers—had the lowest status within the profession. The remote health-care providers were sensitive to being looked down on by the HSC specialists and there was a tendency for specialists and subspecialists to denigrate the remote physicians' abilities. Therefore, treating the remote site health-care providers with respect was important. A physician involved with multiple specialties teleconsultation project YB commented:

> Interviewer: In terms of dealing with the doctors up there [at the HSC], how has that been?
>
> YB Physician: Well, pretty good. In general, and that's an important key to the success of the program, because, you know, if the doctors make you look good, and let you learn something, then you'll want to come back. But if they make you look bad, then you don't want to do it again. And most of the doctors are really good about . . . you know, even if they feel like you've done exactly the wrong thing, they'll say, "Yes, that was an excellent thought. And I would ask a couple of other things." But there are some guys that are jerks over it, and there was one infectious disease guy that, wooh! I mean, he would sit back and he would say, "What kind of bull____, what kind of asshole, nah, nah, nah, nah . . ." and you could hear him off the screen. You know, I could hear him talking about this off the radio, you know, and . . . we'd just never consult him again. You'd say, never, ever get this guy again.
>
> Interviewer: Did you end up, for example, that one was infectious disease. Are there other people in that field that you can end up working with, or . . . ?
>
> YB Physician: Yeah, there was another infectious disease guy that was great. He was great. Very patient. Good. But this one guy had a burr up his saddle and

> we'd consult him a couple of times, but each time, he was like he needed a personality transplant or something.

Ironically, the teleconsultation sessions that added value often ended up resulting in fewer teleconsultation sessions because the remote site health-care providers were able to handle cases by themselves that they previously would have had to collaborate on. The director of telemedicine at site Y felt this resulted in a 30 percent reduction in the number of teleconsultation sessions engaged in:

> HSC Y Physician: But you can teach, as a matter of fact, the presenter is the biggest benefactor of all this because, after awhile, he becomes damn sharp talking to the chair of orthopedics one hour a week. After awhile, well, why in the hell am I going to present that case again? I already know how to handle it. So the education that goes on for the presenter, whoever he is, at whatever category, is absolutely, you become super at what you do. And, therefore, they use the teleconsultative services is like this, whew! And then it goes down, well why? Because I can handle a hell of a lot. How much could they handle that they could not handle before? I'd say 30 percent!

However, those teleconsultation sessions that did occur enabled the remote sites to handle even more complex problems than they had been able to handle before. A remote site physician at XB made the comment that the teleconsultations had become their "workhorse" for treating infectious diseases, and that they were "taking care of more cases and more complicated cases" as a result of the teleconsultations.

Discussion

THIS RESEARCH EXAMINED COLLABORATIVE ACTIVITIES in virtual settings from a knowledge management perspective in order to better understand how collaborative activities enable two or more parties to achieve outcomes the parties would find difficult or impossible to accomplish on their own. Collaborative activities involving knowledge transfer, discovery, and creation—and the subsequent application of such knowledge—were focused on. The findings indicate a strong association between the collaborative activity and the type of telemedicine activity in which the telemedicine projects engaged, and the impact such projects were perceived as having on remote site health-care delivery. Table 4 presents a categorization of the different telemedicine projects by the telemedicine activities in which they engaged and their primary collaborative activities. The boldfaced telemedicine projects are those that affected remote site health-care delivery in a positive manner. This framework correctly differentiated between those telemedicine projects that affected remote site health-care delivery in a positive manner and those that did not in nine of the ten cases. Only telemedicine project WA was incorrectly discriminated.

The data suggest that both the distance learning and teleconsultation projects had to involve either knowledge discovery or knowledge creation as their primary collaborative activity. If either of these telemedicine activities primarily involved knowledge

Table 4. Telemedicine Projects Classified by Telemedicine and Collaborative Activities

	Teleradiology	Distance learning	Teleconsultation
Knowledge creation			**XD (21)**
Knowledge discovery		**WB (21), XC (21)**	**YB (21), WC (19)**
Knowledge transfer	**YA (16)**, WA (12)	XB (12)	YC (12), XA (11)

Note: Boldfaced items affected remote site health-care delivery positively.

transfer, then these telemedicine projects did not impact remote site health-care delivery in a positive manner. Of the five telemedicine projects involving teleconsultations, three affected remote site health-care delivery in a positive manner. These three also involved knowledge discovery or knowledge creation as the primary collaborative activity in the teleconsultations. In contrast, the two teleconsultation projects that did not have a positive impact on remote site health-care delivery involved knowledge transfer as their main collaborative activity.

The same held true for the distance learning projects. The two distance learning projects that affected remote site health-care delivery in a positive manner involved knowledge discovery as the main collaborative activity. In contrast, the one distance learning project that did not have a positive impact involved knowledge transfer as the primary collaborative activity.

The collaborative activity by telemedicine activity classification scheme also held in terms of the teleradiology projects. While both of the teleradiology projects involved knowledge transfer as the primary collaborative activity, only one had a positive impact on remote site health-care delivery. The classification scheme did not break down in this instance; rather, in the case of teleradiology project WA—which appears incorrectly discriminated—the social context dominated and explained why the project did not impact remote site health-care delivery in a positive manner.

The social context plays an important but subsidiary role to the type of collaborative activities engaged in on the value telemedicine projects are perceived as having. Telemedicine projects involving a mismatch between the types of collaborative activities performed and those needed are unlikely to have a positive impact on remote site health-care delivery—regardless of the social context in which they exist. However, the social context can have a significant influence on the success of telemedicine projects when the collaborative activities needed are the same as those provided. Collaborative activities are collective in that they involve the parties working together and combining their knowledge and expertise in often subtle ways to reframe, refine, or reorder the problem at hand and the possible courses of action. A supportive social context also supports and maintains the personal component and absorptive capacity that are important to effective knowledge transfer, discovery, and creation. It is criti-

cal that the social context in virtual settings facilitates the open interaction and trust development needed for collaborative activities [40, 58]. Without a supportive social context, even the simplest of collaborative activities in virtual settings are unlikely to be valued.

This was best illustrated by teleradiology project WA, which did not have a positive impact on remote site health-care delivery. Teleradiology is not very sophisticated from a technology perspective in that it involves asynchronous file transfer, and digital radiography is well accepted in the radiology profession. Further, teleradiology involves the fewest process changes from the perspective of the radiologist, the primary care provider, and the patient, and it is one of the few telemedicine activities for which the specialists were reimbursed for participating, Teleradiology involved the least complex type of collaborative activity—the transfer of explicit knowledge. These conditions suggest that if there was a collaborative activity for which the social context would matter the least, it would be teleradiology. Yet teleradiology project WA did not have a positive impact on remote site health-care delivery because of the lack of trust and respect between the radiologists and the primary care providers involved. In other words, the social context not only did not facilitate effective collaborative activities but was the major barrier to effective knowledge transfer.

The results highlight the importance of the tacit knowledge component in collaborative activities in virtual settings. Collaborative activities in virtual settings can result in high levels of tacit knowledge being communicated and applied; when they do, then the projects of which the collaborative activities are composed can have significant impact. In the telemedicine projects studied, the teleconsultation and distance learning projects that had a large tacit knowledge component tended to impact remote site health-care delivery in a positive matter, while those that involved primarily explicit knowledge transfer tended not to have a significant impact.

Collaborative activities with a more tacit dimension were perceived as more valuable because they enabled decision makers to customize the explicit knowledge to the relevant situation at hand. Collaborative activities involving primarily explicit knowledge were less valued because they either involved the transfer of knowledge that the local decision makers already possessed or they involved knowledge that was too abstract or theoretical to be of practical use for the current situation. In the case of health care, primary care providers, knowingly or not, follow clinical practice guidelines that work or, at least, have worked most of the time. Therefore, the transfer of explicit clinical practice guidelines from the specialist to the primary care physician was of limited value. Instead, the primary care providers needed reassurance and help in understanding why the clinical practice guidelines they applied broke down in that particular instance. In other words, the primary care providers need help in customizing and combining the generalized explicit knowledge of clinical practice guidelines with their tacit and deep knowledge of the complex problem at hand. Such efforts require the primary care providers to identify and understand more subtle distinctions than the explicit knowledge contained in the clinical practice guidelines enabled them to make. The primary care providers needed to apply their experiences and judgment to the unique problem at hand. This involved the use of tacit knowledge, which, when

combined with explicit knowledge, could efficiently and effectively address the complex problems faced through the collaborative activities of knowledge transfer, discovery, and creation.

The application of both tacit and explicit knowledge was needed for telemedicine projects to be successful. While the teleradiology projects generally involved the transfer of explicit knowledge, where the radiologist communicated the diagnosis, they also involved the application of both tacit and explicit knowledge by the radiologist when he or she interpreted the radiographic images. Teleradiology projects had a positive impact when they involved solely explicit knowledge transfer, and the distance learning projects involving primarily explicit knowledge transfer did not, because the application of teleradiology involved the radiologist applying tacit knowledge that the primary care providers did not have. The distance learning projects did not help the medical students in their actions because it provided generalized explicit knowledge when contextualized tacit knowledge was needed. Explicit knowledge is useful only if it is a tool that helps decision makers [53]. In the case of the distance learning projects, the decision makers (the medical students) already had the tool (the explicit knowledge) or lacked the tacit knowledge and absorptive capacity—due to their limited experience—to personalize and apply the tool to local conditions. In contrast, multiple specialties teleconsultation project YB provided an excellent example of how ICTs can be utilized to facilitate the application of tacit knowledge in knowledge discovery activities in virtual settings.

While one type of knowledge without the other may be useful under certain circumstances, the real value of collaborative application in virtual settings occurs when both explicit and tacit knowledge are combined. This enables the relevant decision makers to address complex, messy, and often paradoxical problems. The value of collaborative activities is the ability for two or more parties to achieve outcomes that the parties would find difficult or impossible to realize on their own, and a knowledge management perspective addresses the issue of how such activities enable these outcomes in terms of their ability to transfer, discover, or create knowledge.

The types of ICTs deployed also need to be considered, as they may have a significant influence on the ability of the parties to engage in knowledge discovery and creation. The association between the types of collaborative activities and the IT configuration is exhibited in Table 5. Still image transfer did not provide the parties involved with the ability to interact with each other in real time. Although this was not a barrier to knowledge transfer activities, it is likely that such limited capabilities will not facilitate significant knowledge discovery and creation activities. In contrast, the interactivity of videoconferencing and multimedia facilitated knowledge discovery and creation activities in virtual settings.

Interestingly, videoconferencing and multimedia used primarily for knowledge transfer were not perceived as being valued. In this research, videoconferencing and multimedia equipment were viewed as different IT configurations. Given the convergence of videoconferencing and multimedia capabilities in terms of the newer collaboration tools available, this differentiation is not likely to hold in the future. What is relevant is that knowledge discovery and creation activities appear to require relatively rich

Table 5. Telemedicine Projects Classified by Collaborative Activities and IT Configuration

	Still image transfer	Videoconferencing	Medical multimedia
Knowledge creation			**XD (21)**
Knowledge discovery		**WB (21), XC (21), WC (19)**	**YB (21)**
Knowledge transfer	**YA (16)**, WA (12)	XB (12)	YC (12), XA (11)

Note: Boldface items affected remote site health-care delivery positively.

communication media. However, the use of such rich media for relatively simple tasks such as the transfer of explicit knowledge may not be necessary or even desired because other, more convenient media such as e-mail and facsimile are available and sufficient. Thus, it appears that telemedicine projects utilizing rich media to perform routine tasks are unlikely to impact remote site health care delivery in a positive manner—regardless of the social context in which they operate.

Contributions to Research and Practice

THIS PAPER MAKES A NUMBER OF CONTRIBUTIONS to research. It provides a useful and different viewpoint on collaborative activities in virtual settings by applying a knowledge management perspective, and it extends research of knowledge management into the phenomenon of collaborative activities in virtual settings. This research demonstrates how collaborative activities facilitate the leveraging of knowledge assets by enabling the communication and application of tacit knowledge without the often impossible task of converting it into explicit knowledge. This research has provided insights into how ICTs in general, and telemedicine in particular, can help organizations manage different facets of collaborative activities in the form of knowledge transfer, discovery, and creation—depending on the type of projects engaged in and the technology utilized. By utilizing a knowledge management perspective, this research contributes to a better understanding of how collaborative activities in virtual settings enable two or more parties working together to achieve objectives that would be difficult or impossible to realize on their own.

Collaborative activities are emergent knowledge processes, and this research has addressed calls for developing a better understanding of designing information systems to support such processes [2, 28, 51]. While this research focused only on virtual collaborative activities in health care, it is likely that these findings are applicable to other industries engaged in such activities in virtual settings. Given the trend of increasing globalization and the focus on engaging in collaborative knowledge work regardless of the location of the participating individuals, these are significant contributions.

This research has also made a number of such contributions to practice. Globalization means that the collaborative activities needed to address increased environmental complexity are increasingly occurring in virtual settings. This research provides a link between the type of collaborative activities and the impact such activities are likely to have. To better gauge the potential impact of collaborative activities in virtual settings, managers need to carefully assess whether the type of collaborative activities they propose to engage in are appropriate for the situation at hand and the personnel involved. Collaborative activities in virtual settings are capable of having a significant impact on the future capabilities of the participants, and managers must pay attention to the educational component of such projects if their organizations are to reap the potential benefits. The social context of projects involving collaborative activities in virtual settings can have a significant effect on the impact such projects have, and managers need to take steps to foster a supportive social context. This may include taking steps to integrate the participants into a coherent, if temporary, social network. Managers also need to consider whether projects involving collaborative activities in virtual settings are appropriate in times of crisis. This research indicated that crisis situations in virtual settings may be more effectively handled by reframing the problem such that it involves a more structured decision-making process.

Limitations and Future Research

THIS RESEARCH IS NOT WITHOUT ITS LIMITATIONS. Given the limited sample size, the findings need to be replicated in both telemedicine and other virtual settings. This research may be subject to common methods bias in that the primary sources for determining the collaborative activities and how the telemedicine projects affected remote site health-care delivery were the same. The primary sources in both cases were the key informants. No other source for the type of collaborative activities engaged in existed, and the availability of additional sources to determine how the telemedicine project affected remote site health-care delivery was limited for two reasons. First, legal issues prevented the researcher from having access to patient records. Second, consistent with the experiences of other research in telemedicine [36], many of the sites did not maintain such records. Therefore, it was often difficult to find other sources by which to assess how the telemedicine projects affected remote site health-care delivery. However, the triangulation of key informants between the different functions and different sides of the projects may have mitigated the impact of common methods bias because the different parties often had a different perspective or different interest in how the telemedicine projects were perceived. Therefore, it can be argued that the effects of common methods bias in this research were minimized.

This research has focused on the collaborative activities that occur in virtual settings. Future research needs to address the processes by which such collaborative activities occur. How a social context supportive of collaborative activities in virtual settings can be facilitated and maintained needs additional research as does how the composition and membership patterns of the virtual teams impact the effectiveness of such teams.

The decision-making processes in which teams engage in collaborative activities in virtual settings needs further research. Dealing with complex, equivocal problems often involves sense making [5, 29, 59], and the phenomenon of sense making in virtual environments needs further research. While this paper has made a contribution to the better understanding of collaborative activities in virtual settings, it is only the beginning of an effort to research this emergent and multifaceted phenomenon.

Notes

1. The one exception was a pediatric oncology teleconsultation project that was discontinued by the pediatric oncologists after a period of four months.

2. In each of the four instances of disagreement, the difference between the researcher's assigned value and the third-party's assessment was only plus or minus one value. The final value assigned to the variable in these cases was determined by negotiation between the researcher and the third-party assessor. Note that the selection of the negotiated value did not affect the determination of the *overall* impact on remote site health-care delivery in terms of it being very positive, positive, and so on.

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