The Architecture and Materiality of IT-enabled Services: An Investigation into Appropriation of Remote Diagnostics Technology

Completed Research Paper

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Abstract

This paper develops a theoretical model to examine how IT is appropriated in business services. By distinguishing between the service level, information level, and artifact level, the model reveals the dual affordances of IT in the context of business services. The mediating affordances are expressed through heterogeneous portfolios of IT artifacts and the tensions between their intended and actual usage. In contrast, the mediated affordances are expressed through diverse signs and the tensions between intended and received meanings. The detailed workings of this model are illustrated by a field study of a remote diagnostics service for machinery within the mining industry. We suggest that the model facilitates a deeper understanding of how IT is appropriated in business services. At the same time, we add to the emerging literature on materiality by revealing the unique characteristics that IT confers on social action.

Keywords: IT-enabled services, materiality, mediated affordances, mediating affordances

Introduction

Contemporary organizations have dealt with the impacts of information technologies (IT) in organizations over the last two decades with a focus on the uses of IT within the confines of inter- or intra-organizational processes and structures (Zammuto et al. 2007). Today, we are witnessing the emergence of a new breed of digitally fostered innovations that involve the pervasive penetration of digital technology in all facets of life (Brynjolfsson & McAfee, 2014; Yoo 2010). The emergence of new products that interact with global digital infrastructures such as the Internet and wireless technologies challenges us to re-think the scope of our theories and empirical analyses. Following this ongoing ”digitalization of everything” contemporary businesses are being transformed, driven by a service-dominant (S-D) logic (Lusch et al. 2007; Vargo and Lusch 2008) and enabled by – and often dependent upon – IT (Barrett and Davidson 2008; Chesbrough and Spohrer 2006; Edvardsson et al. 2000; Kallinikos 2006). Services are traditionally characterized as an ongoing exchange of intangible assets between a provider and a customer (Grönroos 2001; Quinn 1992). Service interactions between the customer and provider has traditionally been anchored in human interactions, but appropriation of IT changes the ways services are conceived, developed and delivered (Rai and Sambamurthy 2006). As firms face intense competition, globalization, demand for innovation, and time-to-market pressures, IT has become a key driver in service innovation (Barrett and Davidson 2008; Chesbrough and Spohrer 2006), leading to the development of new service concepts (Zeithaml and Bitner 2000) and the redesign of existing services (Berry and Lampo 2000; Grönroos 2001). Several ongoing changes in IT-enabled services have been described in the literature and calls have been made to conceptualize and theorize these changes (Alter 2010; Barrett and Davidson 2008; Lyytinen and Rose 2003; Orlikowski and Schultze 2004). Existing research on IT-enabled services tends to focus on the changes caused by increased digitization, which demonstrate how old service characteristics are transformed into new ones. For example, appropriation of IT enables a transformation from local to global services, from non-storable to storable services, from synchronous to asynchronous service co-production and from human–human to human–computer interactions. While these conceptualizations provide important insights into changes in business processes and consumer behavior, they offer little insight into the foundations of IT appropriation in business services.

This shortcoming in current theorizing about IT-enabled services is a reflection of the more general trend within information systems (IS) research to treat IT as a "black box", disregarding the nature and use of IT (Orlikowski and Iacono 2001). To address this limitation, IS scholars have recently begun to examine materiality issues associated with IT (Leonardi and Barley 2008; Orlikowski and Scott 2008; Zammuto et al. 2007), targeting how IT provides "opportunities for and constraints on actions" (Leonardi and Barley 2008, p 162). Leonardi (2007, p 816) viewed IT, including both its physical and non-physical components, on the basis of how "...the impact of its material features is transformed through the social action of collective appropriation." While this materiality perspective has the potential to provide new insights, material agency comes in many forms, and the material agency associated with IT is arguably fundamentally different from that of other technologies and artifacts. However, existing research on materiality treats IT as being similar to other technologies without revealing the unique characteristics that it confers on social action. Against this backdrop, the objectives of this research are to provide insights into how IT is appropriated in and affords business services. Drawing on insights from existing literature about services and affordances, we develop an architectural model of IT-enabled services, which is a new theoretical device for examining how IT is appropriated in and affords business services. We illustrate the workings of the model by a detailed investigation of an IT-enabled remote diagnostics service for machinery and equipment within the mining industry. Access to rich data allowed us to demonstrate the appropriation of IT at different levels of granularity and to understand in detail how the material and the social interacted as the provider and the customers co-produced the remote diagnostics service. Drawing on current theory relating to IT-enabled services and material agency associated with IT, the model contributes a three-level architecture as a foundation for understanding business services by evoking subsets of heterogeneous portfolios relating to information services and IT artifacts. In addition, the model distinguishes between the mediating and the mediated affordances of IT to explain how the material associated with IT affords business services.

The architecture of IT-enabled services

The distinction between products and services is increasingly blurred. A fundamental argument used to distinguish services from products is the inseparability of service production and consumption. Questioning this distinction, Vargo & Lusch (2008) made a distinction between co-production and co-creation, where co-creation is not focused on the production process, but rather on the outcome of the service and the value that results, for both provider and recipient. Customers are viewed as co-creators of value because their actions affect service outcomes. More recently Vargo & Lusch (2011) have stressed the interchangeability of provider and recipient roles, choosing to use the "more abstract designation" of actor-to-actor relationships. In IT practices, this distinction becomes especially blurred since new services can be added to products through the appropriation of IT (Ramiller et al. 2008). This development leads to products with an increased service component (Spohrer and Riecken 2006) as suggested by the notion of 'the transformation of products to services waiting to happen' (Gustafsson and Johnson 2003). Driven by S-D logic (Lusch et al. 2007; Vargo and Lusch 2008), it is such specialization, combined with the "increasing ability to separate, transport, and exchange information, apart from embodiment in goods and people”, that is transforming modern businesses (Vargo and Lusch 2008, p 4). IT is extensively used by the service sector (Starem et al. 2006) because it provides communication, storage, and processing capabilities, all of which play a central role in service development. Service firms use IT to collect information about customer interactions and purchases in order to improve customization of marketing and service delivery (Rust and Miu 2006). Products, which have had IT components added to them, can, for example, become the eyes and ears of remote service providers, allowing them access to real-time data and providing the opportunity to offer radically improved services to customers (Gershman and Fano 2005).

As a result, there is a growing body of literature about the ability of IT-enabled services to effect change in business practices. Barrett and Davidson (2008) discuss how service characteristics, such as storability and the separation of production from the consumption of services, have changed because of IT. Orlikowski & Schultze (2004) discuss the use of IT to enable automated self-services, where service provision can take place without the direct involvement of the service provider. Examples of IT-enabled self-services include Internet banking, remote customer order entry, and follow-on customer services (Lyytinen and Rose 2003). The appropriation of IT allows services to be successfully automated in the same way that the production of goods has been. Barrett and Davidson (2008) also point out that IT enables information to be exchanged globally, thus challenging the localized view of services. This emerging research about IT-enabled services focuses on characterizing the differences between ‘the before and after’ situations as services are increasingly digitized, without revealing in detail how IT is appropriated in business services. To understand how contemporary use of IT enables new services and the transformation of existing services, Mathiassen & Sørensen (2008) suggest that it is necessary to distinguish between the different levels of a service: the service level, the information level, and the artifact level. On the service level, business services are executed through processes as a reflection of the provider’s relation to its customers (e.g. related to remote diagnostics of industrial machinery and equipment). Hence, the service is co-produced by the provider and the consumer through a series of sequential and parallel steps (e.g. employees working remotely for the diagnostics service provider and employees working locally with the monitored machinery and equipment at the customer’s site). On the information level, the actors involved in the business service produce and consume information about the business service (e.g., about vibrations in machinery and equipment) and this information afford the creation of shared meanings about the business service and its co-production. Finally, on the artifact level, a combination of hardware and software services support human–computer interaction, data processing, and data storage (e.g. in the form of PCs and mainframes, cell phones and laptops, networks, and related software). This level facilitates data capture about the service and its co-production as well as sharing of that data amongst the involved actors regardless of location. As summarized in Table 1, IT-enabled services are thus configured into a three-level architecture, in which business services are afforded by information services which, in turn, are afforded by different forms of IT artifacts and software services.

Level	Key construct	Content	Example
Service level	Process steps	Business services are co-produced in steps by providers and customers, and afforded by information services and IT artifacts.	Diagnostics and maintenance services in the mining industry enacted in the collaboration between service technicians and customers.
Information level	Information services	Information services afford the creation of shared meaning amongst involved actors about the business service and its co-production.	Information services for the collection and analysis of vibration data, for presenting analysis results, and to support collaboration and discussion between service technicians and customers.
Artifact level	IT artifacts	A combination of hardware and software services affords data capture about the service	Sensors and central monitoring units, cell phones and laptops, networks,

		and its co-production as well as sharing of data amongst involved actors regardless of location.	diagnostics software, and software to support remote access to equipment.

Table 1. The Architecture of IT-enabled Services

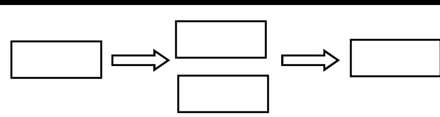
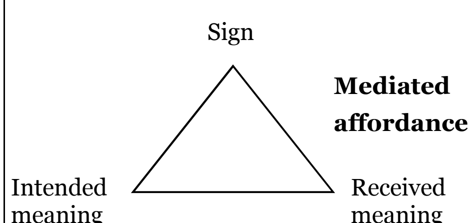
This view of IT-enabled services goes beyond the traditional systems perspective within the IS discipline (Mathiassen and Sørensen 2008). Mathiassen and Sørensen argue that the traditional information systems perspective suggests that IT solutions comprise homogeneous packages of applications that interface with other systems to provide generic support for complex business processes. In contrast, the services perspective suggests that organizational actors constantly use subsets of heterogeneous portfolios of information services and artifacts as part of their every-day use of IT. Building on theory about organizational information processing (Daft and Lengel 1986; Galbraith 1974), the assumption is, that users appropriate IT through the ongoing configuration of heterogeneous portfolios of artifacts responding to their information processing requirements in order to produce the specific business services they are involved in. The services perspective also draws on Ramaprasad and Rai's (1996) distinction between generation and dissipation of information (we adopt 'production' and 'consumption' to denote 'generation' and 'dissipation' in their theory). Production is the translation of organizational stimuli in business processes into information, whereas consumption is the translation of information into new organizational stimuli within business processes. Ideally, the relationship between information production and consumption is designed and managed such that each positively reinforces the other. Such feedback will help organizational actors avoid information being produced without it being consumed, and ensure the production and sharing of information required to produce the service. Agents (human beings, computers, and others capable of conducting logical work) differ in their capacity to produce and consume information and to add value to the related business service. We posit that the three-level architecture and related understanding of artifact usage, allows us to address the complexities involved in IT-enabled services by separating the conflicts that exist between their constituent components. To understand how interactions between human and non-human actions afford the production of IT-enabled services, we next elaborate on the architectural model by examining the unique characteristics of IT materiality.

The materiality of IT-enabled services

As a result of the demand for detailed analysis of IT (Monteiro and Hanseth 1996; Orlikowski and Iacono 2001), materiality has received increased attention as a new conceptual foundation for theorizing about the IT artifact (Leonardi and Barley 2008; Orlikowski and Scott 2008). Materiality refers to some property of the technology that provides users with the capabilities to perform actions (Leonardi 2010). Building on the work of Gibson (1986), Leonardi (2010) argues that the material affords a variety of actions depending on the context in which it is appropriated and the ways in which an actor perceives its materiality. Affordance theory has received increased attention as a new conceptual foundation for theorizing about the enabling and constraining effects of IT materiality (Hutchby 2001; Leonardi 2011; Leonardi and Barley 2008; Zammuto et al. 2007). Specifically, Leonardi and Barley (2008) suggested that the prediction of organizational change caused by technology would be improved by developing a language of constraints and affordances. The affordance concept originates with the perceptual psychologist James J. Gibson (1977; Gibson 1979) and refers to properties of the environment that can enable or constrain behavior. For example, a vertical surface like a tree may provide support for one animal, but not for another. The vertical surface affords action possibilities that exist independently of an animal's ability to recognize them and Gibson argued that affordances can be seen as action possibilities that are latent in the environment. While affordances in this way are objective and independent of the animal's ability to recognize them, they are, at the same time, relative to actors and dependent on those actors' capabilities.

Affordance theory was later adopted to the Human Computer Interaction (HCI) field by Norman (1986) to refer to action possibilities that are readily perceivable by an actor. According to Norman, affordances provide actors with suggestions of how an object may be interacted with. Affordance theory has also been adopted by the IS field to explore the materiality of technology and to demonstrate how it favors, shapes, or invites, whilst at the same time constrains, work practices. Hutchby (2001) drew on the affordance concept in his reinterpretation of earlier case studies to illustrate a way of analyzing the materiality of IT artifacts. In their study of interactions in photocopier rooms, Fayard & Weeks (2007) conceptualized the social and physical characteristics of an environment that can afford informal interactions. Markus and Silver (2008) introduced the term "functional affordance" that refers to the things a user may be able to do with the artifact, given their capabilities and goals. In his study of predicting technology-induced change, Leonardi (2011) introduced the notion of "collective affordances" to describe how disparate technologies-in-use may become shared technologies-in-practice. Finally, Zammuto et al. (2007) proposed the term "affordances for organizing" to conceptualize the process by which IT and organizations are intertwined and evolve over time. In their study, Zammuto et al. listed five possible affordances that characterize the relationship between IT and organizations: 1) visualizing entire work processes; 2) real-time/flexible product and service innovation; 3) virtual collaboration; 4) mass collaboration; and 5) simulation/synthetic reality.

Even now, with the possible exception of the work of Zammuto et al. (2007), the adaptations of affordance theory that give an understanding of how technology is appropriated in organizations are dominated by Gibson's (1977; 1979) initial work. Gibson focused on the relationship between an animal and its environment and how certain features of the environment enabled and constrained the behavior of that animal. This framing represents a tool metaphor in which a person uses technology to attempt to achieve certain targets (Ehn 1988). The dominant position of the tool metaphor implies that current adaptations of affordance theory largely consider IT as being similar to other technologies. However, material agency comes in many forms and the material agency associated with IT is, arguably, fundamentally different from that associated with, say, a speed bump, a key, or an airplane. In fact, in the context of complex business services, IT is not only a tool for data processing; more importantly, it mediates meaning between actors across the environments in which they are situated. Hence, combining the basic architectural model of IT-enabled services (Table 1) with insights from the existing literature on IT materiality, we conceptualize the unique characteristics of how IT affords business services. As detailed in the following, and summarized in Table 2, we distinguish between mediated and mediating affordances to reflect the dual affordances of IT. Mediating affordances are concerned with form whereas mediated affordances are concerned with content, and together they enable actors to carry out IT-enabled services. Focusing on mediating affordances allows us to examine how actors maneuver IT artifacts between their intended and actual use. Similarly, focusing on mediated affordances allows us to examine how actors maneuver meaning between the intended and received meaning.

Level	Key constructs	Description
Service level	 Business process steps	The transformation of information into action within a business process practice is afforded by information transfer mediated by IT artifacts and translation into meaning mediated by signs.
Information level		Information translation into meaning is mediated by signs that are articulated with an intended meaning in mind, which may or may not correspond to the received meanings.

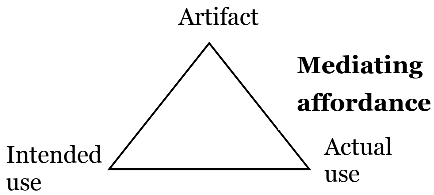
Artifact level		Information transfer is mediated by IT artifacts that are designed with an intended use in mind, which may or may not correspond to their actual use.

Table 2. The Materiality of IT-enabled Services

The basic distinction between mediating and mediated affordance is consistent with how materiality has been represented in the media discourse since the 1960s. This representation is defined by Marshall McLuhan's notion (1994) of media as "extensions of man", which includes any material in unfixed form, or even formless material, such as electricity. This notion of materiality, which articulates the important relationships between the form and the content of a medium, has been further developed in Andersen's discourse on computers as media (Andersen 1990). As with an electrical wire that has the ability to transfer electricity, the computer comprises physical components (e.g. hard drive, processor, memory, screen and keyboard) that have the ability to process and share data. The distinct between mediating and mediated affordances also has similarities with the operand and operant resources in service-dominant logic (Vargo and Lusch 2004). Like operand resources the artifact level (mediating affordances) reflects the physical artifact whereas the information level (mediated affordances) reflects the non-tangible information.

Mediating affordances focuses on the process of information transfer and refers to the form of the medium and the sharing of data between actors. Form of the medium can refer to cognitive form (e.g. clear and precise words on a button label); physical form (e.g. adequate size and accessibility of a button); sensory form (e.g. seeing, hearing, feeling); and functional form (e.g. the button performs the intended function) (Hartson 2003; Norman 1986). Although artifacts have an intended use built in by the designer, actual use is determined by actors as they use the artifact in either intended or unintended ways. This interplay between the intended design and the actual use of IT artifacts is examined in IS research (Koopman and Hoffman 2003) and has been explored in a number of studies. Gasser (1986) identified workarounds as a user strategy for coping with situations where elements of the actual use of the artifact were not part of the design. McGann and Lyytinen (2005) distinguished between planned and improvised use of IT and suggested that the improvised use can either be supported by a flexible IT solution (configured IT improvisation) or by adjusting the artifact in ways it was not designed for (IT workaround). In a similar vein, Orlikowski (1996) introduced the concept of "situated changes" where transformation of the technology emerged from practical use. In activity theory artifacts is described as tools that are used to complete a task where the tool or technology has intentions from a design view that is materialized in future use situations (Kaptelinin 1996). We define the mediating affordances of IT as the ability of IT to afford information transfer processes.

Mediated affordances focuses on the information translation and refers to the content of the mediated through which the involved actors seek to create shared meaning through the communication of signs. A sign consists of an ordered sequence of symbols with an intended meaning and presented in the form of gestures, sound, text, or other means of visualization. Hence, information translation is preceded by a process in which signs are created with intended meanings (Desouza and Hensgen 2002). In organizations, signs are created about entities and processes in various forms (e.g. qualitative or quantitative, aural or visual, and structured or unstructured) and by various means (e.g. formal measurement, observation, discussion, and computation) (Ramaprasad and Rai 1996). As signs are communicated, a translation process occurs in which actors interpret the sign to arrive at perceived meanings (Desouza and Hensgen 2002; Ramaprasad and Rai 1996). We defined the ability of IT to afford information translation between actors as the mediated affordances of IT.

Research Methodology

Our theorizing is grounded in a qualitative field study of networked maintenance at Luossavaara-Kiirunavaara AB (LKAB) and the remote diagnostics company Monitoring Control Center (MCC). We followed the basic principle of case studies to get an in-depth understanding of the phenomenon (Cavaye 1996; Yin 2003), which in our case meant investigating the daily work in networked maintenance and the effects and implications it had for the involved people and organizations. The studied remote diagnostics service was co-produced by the Monitoring Control Center (MCC) and the mining company Luossavaara-Kiirunavaara AB (LKAB). MCC was established in 2003 as a competence center for the maintenance and monitoring of machinery and equipment in mining, minerals processing, and cement industries around the world. MCC's remote diagnostics service involves the collection and analysis of data, communication of diagnostic results, and assisting customers in making decisions based on those results. LKAB was established in 1890 and is one of the world's leading producers of upgraded iron ore products for the steel industry, as well as a growing supplier of industrial minerals products to other sectors. In 2002, LKAB initiated a project aimed at increasing its productivity without any major investments. This project focused on reducing downtime and unplanned work stoppages by developing new maintenance routines and processes within the company. The project involved changes in work routines for the operators, as well as new ways of working with external partners. As part of this project, LKAB decided to employ more preventive maintenance using remote diagnostics technology. MCC became the main supplier of these services.

We conducted a total of 33 interviews with key stakeholders (10 from MCC and 23 from LKAB). We collected data at different occasions between 2004 and 2010 with access to different respondents that could help us develop our understanding of remote diagnostics services. The recurring data collection thus served to give us detailed insights into the service from different perspectives. In addition to the interviews, we collected publications from LKAB and MCC. The sampling of interviews was purposeful (Strauss and Corbin 1990) focusing on LKAB employees in top and middle management, group managers, maintenance planners and technicians with important relations to networked maintenance. At MCC, we talked to all categories of involved employees including management, technical developer and analysts. The interviews were semi-structured and open-ended to reveal the everyday work practice and the respondent's use of different technologies at work. Each interview lasted between one and two hours, and all interviews, except three, were conducted face-to-face at the respondents' workplace, which provided us with contextual understanding and insights into the work process within each company. Although key informants helped us identify relevant interviewees, participation in the research was strictly voluntary. The first author conducted the interviews together with a fellow researcher. We ended the data collection when we had achieved saturation, i.e., when additional interviews did not reveal new insights. Three data collection engagements during 2003-2006 with purposeful sampling were complemented with two follow up interviews in 2008 and 2010 where we talked to the manager and an analyst to complement our data and get knowledge of how the remote diagnostics service had been consolidated.

To analyze the data, we followed recommended procedures for qualitative research (Eisenhardt 1989; Miles and Huberman 1994), using related literature to guide the process through three steps of coding. The first round of coding involved the first author (who had collected the data) re-reading all data material to become immersed in the data and look for central themes. During this work the researcher took notes and highlighted key phrases that were representative for the respondents. This round of coding was open-ended (Strauss and Corbin 1990) and helped the researcher recall the details of the case, which was important as a number of years had passed since the data was collected. In the second round of coding the first author looked for empirical example of the different level (service, information and artifact level). This served as a basis for discussion between all three authors to refine our understating of the levels and agree upon a common understanding of the case. During these activities we identified the business steps performed in the service work, and the involved services and artifacts. In the third step, we applied the three levels to the case. As there are a lot of information services and artifacts appropriated in the service we selected two information services and three artifacts for the analysis. Although our data analysis progressed primarily from empirical towards conceptual analyses, there were constant interactions, with empirical material leading to specific conceptual characteristics and conceptual reflections triggering further analysis of the data.

Applying the model to remote diagnostics services

Remote diagnostics services rely on the accuracy, availability, volume, multi-dimensionality and extended time-spans of new forms of data representing production states and objects. These services are made up of collections of heterogeneous technologies: sensors that collect data; networks that transmit that data into a centralized repository; and analytical and operational rule systems that store and retrieve the data, analyze them, visualize them and make recommendations, generate alarms or initiate responses. Sensors are located in critical physical components throughout a plant or an industrial network (Han and Yang 2006). Depending on which types of sensors are installed, the remote diagnostics service can, for instance, collect data on the vibrations, the temperature, the pressure and the speed of relevant components. By monitoring such data, it is possible to detect problems in the equipment at an early stage. Remote diagnostic services are co-produced between maintenance team managers in a plant and technicians at a remote service center. The technicians receive data afforded by multiple artifacts and can collect additional data via maintenance team managers at the plant. They are responsible for collaborating with, and making recommendations to, the maintenance team managers in the plant. Remote diagnostics services have led to the centralization of maintenance, something that was previously carried out locally. Remote service centers are located world-wide and monitor and diagnose a large number of distributed industrial equipment and their associated components within multiple organizations. These services have generated new insights and new maintenance practices and rules. Moreover, they increase the information intensity and knowledge intensity of maintenance work because the remote technicians can analyze multiple datasets at a small additional cost. The technicians can also focus on proactively diagnosing problems by learning from past cases and preventing failures through rule-based decision making or through statistical sampling and data mining. By separating local information from its origin, these services produce new ways of organizing maintenance tasks that separate technicians from the equipment and components that they monitor. Next, we illustrate our architectural model by examining the IT-enabled remote diagnostics service, in order to demonstrate the use of the three-level architecture and the dual affordances as analytical channels to understand, and eventually improve, the appropriation of IT in the co-production of services.

Artifact Level Analysis

The production of remote diagnostics services at LKAB and MCC is facilitated by a number of IT artifacts throughout the different steps of the process. Table 4 summarizes the heterogeneous portfolio of artifacts used by the monitoring technicians and the maintenance team managers in their everyday work. At the heart of diagnostics services is the equipment that is monitored either on-line with a sensor system or off-line with a handheld micro logger. Diagnostics software supports the analysis of the measurements and e-mail, mobile phones and reports are used in the communication between the technician and the team manager. The team manager also uses a maintenance system that contains technical information on equipment, and supports work planning based on the information produced by the remote diagnostics service. To illustrate the mediating affordances of IT, three of these artifacts are described from an intended use and actual use perspective. The three artifacts are the condition monitoring unit, the micro logger and the diagnostics software.

Artifact	Used by	Description	Supported tasks
Condition monitoring unit	Service technician	Unit that collects data from permanently installed sensors.	Collection of measurements
Logging computer	Service technician	Stationary computer that collects data from the condition monitoring units.	Collection of measurements
Micro logger	Service technician	Handheld device with sensor for data collection	Collection of measurements
Diagnostics software	Service technician	Software for analysis of data	Adapt diagnostics software, Identify and evaluate exceptions
Archive	Service technician	Contains all collected data	Identify and evaluate

			exceptions
Laptop	Service technician	PC with software and Internet access	Prioritize equipment, Adapt diagnostics software and Identify and evaluate exceptions
E-mail	Service technician, maintenance team manager	Outlook express, regular email software	Decide intervention strategy
Mobile phone	Service technician, maintenance team manager	Sony-Ericsson, regular mobile phone	All
Stationary PC	Maintenance team manager	Traditional stationary PC with required software	Prioritize equipment, decide intervention strategy and check outcome.
Planning software	Maintenance team manager	Maintenance software with technical information on equipment, also used for creating work orders and scheduling	Adapt diagnostics software

Table 3. Portfolio of IT artifacts

Condition monitoring unit

To enable on-line monitoring of equipment, sensors are installed to monitor equipment vibrations. These sensors are connected to a CMU, which in turn is connected to a host (logging) computer. The host computer transfers the collected data to a central server for storage.

Intended use. The CMU is designed to enable round-the-clock data collection. It can be networked and can accept a variety of sensors installed in plant equipment in any industrial or process environment. The CMU collects and evaluates, on a scheduled basis, vibration and other machinery-related data from the permanently installed sensors. Each CMU has between four and 32 digital channels that each handle up to eight sensors. The largest CMUs can thus handle 256 measurement points. The host computer can handle over 60 CMUs, with an overall capacity of 16 000 measurement points. The CMU has a rugged design that allows it to be used in harsh, remote, unsafe or difficult-to-reach locations. All electronic components are placed in a metal cabinet to protect them from dust and dirt (see Figure 3).

Actual use. MCC uses the CMU for the on-line monitoring of plant equipment. However, there are a number of situations where breakdowns occur or when the actual use of the CMU does not correspond to the intended use. MCC monitors mining equipment, which means that some equipment is located underground. CMUs can break down as their data networking capabilities are limited underground. A technician at MCC said: *When the customer installs fiber optics for their control system underground we try to reserve space for monitoring as well, but the capacity is limited*. In fact, when LKAB reconfigured equipment underground, additional networking capacity was installed and reserved for the CMU. The monitoring could then be conducted on-line instead of off-line with the micro logger. However, when no networking capacity is available, measurements still have to be made using a handheld micro logger. Another type of breakdown occurs when the network between the CMU and the host computer is not working and the CMU runs out of memory, causing data to be lost. Finally, breakdowns of CMUs have occurred after power outages that require them to be reset. This is rather time consuming as the CMUs are spread all over the plant.

Micro logger

Equipment that is not monitored on-line is monitored off-line with a micro logger. The micro logger is a portable handheld artifact with a sensor to collect data from the equipment it is connected to (see Figure 4).

Intended use. The micro logger affords collection and storage of vibration and process data. It can handle route based as well as non-route based data collection. For route based data collection, the routes are designed using the diagnostics software installed on a separate computer. The routes are then loaded into the micro logger via a connecting cable. The ability to handle non-route based collection facilitates in-the-field additions and changes to downloaded routes. The micro logger has a sensor that is applied to the bearing house of the equipment. The sensor is magnetic to ensure a firm fit during the logging procedure. After a predefined time (depending on the monitored equipment), the sensor is removed from the bearing house and is ready to be attached to the next equipment that is to be monitored. After the route is completed, the micro logger is connected to the computer and the collected data is transferred into the diagnostic software for analysis. The micro logger has a rugged design to enable it to work in a harsh and dirty industrial environment. It has a 240 × 160 pixel display, and cursor keys and a numeric keypad for navigation and input.

Actual use. MCC uses micro loggers as intended for handheld measurements in industrial environments. The devices are mainly used underground because the networking capacity necessary for online measurements is problematic in this environment. The technicians thus bring the micro logger with them and drive underground to the level where the equipment is located. They then attach the magnetic sensor to the equipment to collect the measurements. The technicians can experience different types of breakdown. First, the low lighting levels underground coupled with a very dark display on the micro logger make it difficult for the technicians to read the text on the display. A technician at MCC explained the challenge: *When you stand down in the mine you see nothing [on the display], you need a flashlight to light up the micro logger*. A second type of breakdown occurs as a result of the battery life of the micro logger being limited to between four and five hours. As the underground routes are time consuming, technicians sometimes have to interrupt the process and go back to the office to recharge the battery before returning to complete the route. A third type of breakdown is related to the functionality of the micro logger. Frequently, the micro logger freezes during the transfer of collected data to the computer, as explained by a technician at MCC: *I can be out and collect data for four to five hours. When I get back to the office [and begin the data transfer to the laptop] everything freezes. Then I have to hard reset the micro logger so it takes a long time to transfer the data. Sometimes the data is even lost and I need to go back and do the measurements all over again. It isn't that much fun to have to go out and do four to five hours of measurements all over again*. To avoid this problem, the technicians often bring their laptop when they collect equipment measurements. They then connect the micro logger to the laptop to ensure the data transfer is successful.

Diagnostics software

The technicians use diagnostics software to produce information on the equipment's condition by analyzing the vibration data that is collected either on-line or with the micro logger. The data collected on-line is transferred from the sensors to the CMU and also via the host computer to an archive, where it is stored in a database. The diagnostics software is connected to the archive and does not use any data from the local computer.

Intended use. The diagnostics software is intended to be used for analysis of vibration data collected on-line or off-line with micro loggers. The diagnostics software contains functions to create virtual representations of the equipment as a basis for the data analysis. In the analysis mode, the software visualizes the collected data and helps the technician identify and examine different trend curves, and view multiple plots together. The software is multi-tasking in the sense that the CMU continues to collect and process data and the technician is notified of real-time operational problems even while using the system for analysis. Additional diagnostic functions enable the technician to view measurement data just seconds after it has been acquired. The program contains event logging, reporting functions and database management tools that afford the close tracking of equipment problems, indicating whether maintenance is required and recreating the events that led up to the current condition. When new equipment is to be monitored, equipment-specific information is loaded into the software. A virtual representation of the equipment and components is created using all the available information, for example bearing type, engine type and data about the specific bearing.

Actual use. MCC uses the diagnostics software as intended: for analyzing vibration data collected on-line or off-line. The diagnostics software is the main artifact that the technicians use on a daily basis. However, a number of breakdowns can occur. First, the connection to the archive may be problematic, as was explained by one technician: *There have been a lot of problems with the server communication. Then we* *cannot work as we don't get access to the server [which contains the measurements].* Another type of breakdown relates to re-analyzing historical data. If the technician discovers an increasing trend curve in a vibration spectrum, the software allows that trend to be isolated so that it can be tracked over time. This is done by specifying the range of frequencies of that vibration: the software then displays only the vibrations between the specified frequencies. In order to examine how fast the trend is growing, historical comparisons would be beneficial. However, the diagnostics software does not contain any functionality for re-analyzing historical data at certain frequencies. A technician explained this lack of functionality: *It's very difficult to re-analyze historical data; the diagnostics software only supports functions for analysis of current data*. Although there are some breakdowns in the actual use of the diagnostics software, the technicians all greatly appreciate the ways in which it affords analysis of the condition of the equipment.

Information Level Analysis

The purpose of remote diagnostics is to analyze equipment measurements as a basis for making decisions about interventions. A variety of information records precede and result from the analysis of the collected measurements. The involved actors translate this information to help establish a shared understanding of the equipment's condition. Table 4 summarizes the different information records that are involved throughout the remote diagnostics process. Drawing on the information level perspective, we analyze the intended and perceived meaning associated with two of the key records, the virtual representation of equipment and the analysis report.

Information record	***Description***	***Supported task***
Assessment report	The role and criticality of equipment are assessed and turned into information about appropriate techniques to select for monitoring. This assessment report is sent to the LKAB maintenance team manager. After sharing the report with the MCC technician, they discuss its content where the two actors' perceived meaning of the prioritization can be shared	Prioritize equipment Connect selected equipment
Virtual representati on of equipment	MCC technician collects technical information on equipment through meetings and telephone calls with LKAB maintenance team manager and creates representation of each piece of equipment in the diagnostics software.	Adaptation of diagnostics software Collect measurements Identify and evaluate deviations
Condition data	Equipment vibrations are turned into information through sensor measurements.	Identify and evaluate deviation
Analysis report	The vibration measurements are further analyzed to provide information on the equipment's condition. Based on the analysis report and previous post-intervention information, the LKAB maintenance manager decides upon an intervention strategy after having discussed his received meaning with the MCC technician.	Decide intervention strategy
Post-intervention information	Post-intervention equipment condition is measured and analyzed to assess the effects of the intervention.	Decide intervention strategy

Table 4. Portfolio of information records

Virtual representation of equipment

This record contains information on the equipment being monitored. The virtual representation of the equipment is created in the diagnostics software and used in the collection and analysis of condition data.

Intended meaning. The virtual representation of a piece of equipment is intended as the basis for the collection and analysis of measurements from that unit. A technician at MCC described it as follows: *We build a virtual representation of a machine that is identical to its physical counterpart. For example, we build a transporter with all of its components, such as the electrical engine and gearbox, and we also add measurement points to the virtual machine. Then we add all available technical data on the electrical motor and the gearbox. The supplier has information about the bearing type, the kind of motor and its bearings.* To develop this representation, the technician combines the technical data about each piece of equipment with preinstalled data in the software, such as data on typical bearings and the number of teeth on the bearings in a gearbox. However, it can be difficult to obtain accurate data about LKAB's equipment. A technician at MCC remarked: *Sometimes when I need certain information I go to the customer and we search for a drawing, but we can't find it. Then I call the equipment supplier, but they don't want to share the drawing with me. Then I contact the customer and ask them to push the supplier to get access to the drawing. It would be much easier if the information was delivered with the purchase, but that's not the case today*

Received meaning. The virtual representation of each piece of equipment allows the technician to understand the characteristics of the equipment as related measurement data are displayed in the diagnostics software. As an MCC technician explained, the representation displayed on the screen helps him visualize the physical equipment in his mind: *I can see on a spectrum if something is odd. I think it is beneficial to have experience of working with mechanical equipment. When I look at a spectrum from a gear box on the screen I actually see the gear box in front of me.* When a component is replaced in a piece of equipment, the new technical specification for that component needs to be loaded into the software otherwise the received meaning does not correspond to the intended meaning. However, the technical documentation is not always kept up to date by the customer and the process of loading the new information into the software can be time consuming. Hence, there are differences between the intended and received meaning of virtual representations of equipment as a result of information about equipment not being up to date. This is problematic as the virtual representation serves as the basis for defining measurement points and for establishing the routes via which off-line data are collected by LKAB technicians.

Analysis report

This information record contains interpretations of the measurements collected from the equipment. The diagnostics software and the technician play important roles in creating this record. The diagnostics software allows detailed as well as general views of the measurements with the technician using the software and their skills to produce the analysis report.

Intended meaning. The analysis report is written once a month and summarizes the condition of the monitored equipment. The intention is to provide the customer with complete documentation of the diagnostics. The written report is, however, complemented with phone calls. A technician at MCC described that scenario as follows: *If I identify a problem in a machine then I write that in the report. But I also call and explain the problem. In the report I just briefly say that you have a damaged bearing on this machine. Then it is up to LKAB.* Hence, even though the idea is that the customer carefully reads through the report for a comprehensive view of the current condition, the technicians have realized that it is better to write short and descriptive reports; otherwise no one will read them. A technician at MCC explained: *The first report I wrote was extensive. When I sent it I thought I would get some response, but no. Now I've simplified it so you don't need to be an engineer to understand it. When I send it my contact calls and asks follow up questions. That's a sign that he actually read the report. When I write it more briefly they absorb it better.* The format of information in the report can, however, make it less likely that it is actually read and it can also lead to difficulties later on. The developer at MCC said: *Actually it is quite stupid to save it as a Word file, then you can't easily go back in history ... We would be better off making use of historical data to draw conclusions. A word document is not searchable. And 24 documents produced during two years, if you need to read all of them... that's quite useless.*

Received meaning. The reports are interpreted by the representatives at LKAB. Even though the intention is to report conditions in a factual way, the technicians at MCC need to be sensitive to how it may be interpreted. A developer at MCC explained: *The customer may have a piece of equipment in a bad condition. Then a technician from here … points to all the problems [in the report]. The customer may think that that the technician is too careful and just complains about everything. You need to have a shared vision of how to maintain the machines and at what level you should [report problems].* Hence, to establish a shared meaning, face-to-face visits and ongoing discussions over the phone are important. The monthly report is therefore followed up with a meeting where the technician from MCC and the representative from LKAB discuss its content. The MCC technician notes that the customer does not always receive the intended meaning of the report: *We decide a time and meet to discuss the report. Many times [the content of the report] is obvious for us but [the customer] doesn't understand what we mean*. The report has also served as an expert statement. The maintenance team managers at LKAB sometimes use them to put pressure on the maintenance employees: *Sometimes we try to make sure that the MCC technician includes things that haven't been conducted in the report. If it is in the report then it is easier for us to put pressure on the maintenance employees to fix the problem. The words from an external expert are weightier than from an internal guy.*

Service Level Analysis

Drawing on the artifact and information level analyses of remote diagnostics at MCC and LKAB, the service level analysis focuses on how actors transform information into service actions. The business service is carried out in seven business steps and their actions are summarized in Table 5. Two of these steps, 'collect measurements' and 'identify and evaluate deviations', are analyzed in detail to illustrate the IT is appropriated in and affords business services.

Business Step	***Description***
Prioritize equipment (1)	MCC technician prioritizes installed equipment, identifies relevant monitoring technologies through research, and makes an investment proposal. Results in written report that is emailed to, and discussed with, LKAB maintenance team manager.
Connect selected equipment (2)	Based on proposed prioritization, MCC technician discusses with LKAB maintenance team manager which equipment to monitor and which technologies to use. On-line sensor system is installed on selected equipment.
Adapt diagnostics software (3)	MCC technician collects technical information on equipment through meetings and telephone calls with LKAB maintenance team manager and creates representation of each piece of equipment in the diagnostics software.
Collect measurements (4)	Data is collected from the equipment's measurement points, either on-line with the sensor system or off-line with a micro logger. LKAB operators assist in off-line data collection and data is stored in the archive.
Identify and evaluate deviations (5)	MCC technician analyzes the data with the diagnostics software and calls LKAB maintenance team manager to request additional information as needed, and to discuss recent results, as well as to identify and evaluate deviations. Once a month, a written report is emailed to LKAB with an overview of the equipment's condition.

Decide intervention strategy (6)	MCC technician and LKAB maintenance team manager discuss possible maintenance actions face-to-face or on the telephone based on written report and their knowledge and experience of the equipment. LKAB technician performs the agreed maintenance intervention.
Test intervention strategy (7)	MCC and LKAB technicians discuss the outcome of interventions mainly at the monthly meetings and on the telephone. Additional information is collected through equipment inspection by LKAB technician as well as third party actors.

Table 5. Actions in the diagnostic process

Collect measurements

This step aims to transform organizational stimuli in the form of equipment vibrations into information through off-line or on-line measurements. For off-line measurements the technician updates the micro logger with the latest routes and measurement points from the diagnostics software. These routes indicate which equipment to monitor and a suggested order in which to collect the data. Next, the technician collects the measurements from the equipment, as specified by the micro logger. If necessary, the suggested route is altered during the monitoring session. A sensor, temporarily connected to the equipment, records the vibrations of the equipment's bearings. Depending on the type of equipment it may take a while for the sensor to record the information. A technician at MCC described it thus: *If it's a high-speed motor the measurements are quick but if it's going slow you'll have to wait 5 minutes, which feels like a long time.*

To enable equipment measurements to be made, the technician may also have to call the control room and ask them to start or stop the equipment. Down in the mine, these calls can be problematic as mobile phone signals are not always available. The technician then uses one of a number of fixed telephones that are connected at certain places in the mine. Whilst the method of off-line monitoring is time consuming and requires human involvement, on-line monitoring is much more efficient. The information is automatically produced by the installed sensors and transferred to the server, from where it can be accessed using the diagnostics software. Information is thus produced on a regular basis without human involvement. A technicians at MCC put it as follows: *I think the on-line monitoring should be developed, it is the best. If you have uncertainties about a machine you can get the vibration records immediately. You don't have to change clothes, drive to the customer, measure, drive back, take a shower and then begin the analysis. With on-line monitoring you get better quality, you can sit calmly and just look at the equipment*. There are also potential quality issues with off-line information production, since the sensor is not installed in a fixed position. Different technicians, or even the same technician, may apply the sensor slightly differently to the equipment, which can result in variations in the vibration measurements. The comparison of these values over time may thus be problematic. In contrast, the on-line information production is perceived as yielding higher quality data.

Identify and evaluate deviations

This step entails analyzing the measurements collected from the equipment to produce information on its condition. To analyze the off-line measurements, the data is loaded into the diagnostics software before the analysis can begin. With on-line monitoring, the information is produced continuously and the analysis charts are updated with the most recent values. The diagnostics software produces an overall vibration spectrum as well as detailed charts relating to specified frequencies. By looking at the specific frequency of the vibrations, the technician analyzes and produces information about where any damage is located and the type of that damage. When used for bearing monitoring, the diagnostics software produces detailed information on whether the damage is on the bullets, the outer or the inner ring, or, if it is due to mechanical looseness, an imbalance or a problem with lubrication. To produce this information, the technicians look at the overall spectrum as well as at specific frequencies. Damage on a bearing is often first recognized in the detailed, filtered analysis mode. A technician at MCC explained: *There are filtered monitoring modes, called envelope measurements, where we can see the bearing damage very* *early. But if we can see the damage in the speed monitoring [the overall spectrum] then we know from experience that the damage is greater. If we see it very clearly in the speed monitoring, we usually make an urgent call to the customer, but that also depends.*

Vibrations are monitored at different frequencies. For example, in the speed monitoring mode, the vibration values are measured over a wide spectrum covering many frequencies. Different frequencies are caused by vibrations from different parts of the bearing. To enable a specific part to be monitored, measurements can be made at a specified frequency. A technician at MCC described the procedure: *A specific rotation speed may be on the frequency 24 hertz. Then we can build a trend at that frequency and the software removes everything else. For example, you adjust the frequency to cover a range from 23.89 to 24.02 and just analyze on that frequency.* This is an example of the type of filtered analysis that enables the technician to see how the vibration of a certain component develops. Measuring trends at specified frequencies enhances information production as it becomes easier to set alarms and follow the development of damage to a specific component. It would be too time-consuming for the technicians to look at all frequencies for every measurement. The ability to break down these measurements into specific frequencies enables technicians to focus on just the critical ones. A technician at MCC put it as follows: *I don't look at each measurement on the spectrum in detail; if I did, I would need more time. When you look at this you must be able to see it from an overall perspective. If you needed to go deep into everything it would take too much time.*

The analysis of the collected measurements is, however, not just an issue of producing information from a theoretical point of view. The information represents a physical reality that needs to be understood. Hence, experience is invaluable when analyzing spectra to help identify damage. The process of specifying frequencies requires sensitivity and experience in order to avoid overlooking emerging damage. Thus, the analysis is not only a technical process solved by the software. Instead, the software enables the technicians to produce information that they cannot produce on their own. Thanks to the centralization of the service, technicians can share experience and knowledge with each other. A technician at MCC explained that difficult cases are discussed with colleagues: *If someone [a colleague] has a problem or is unsure we get together at his desk, we all look at the screen and we discuss the problem, maybe someone has seen this phenomenon before.* These collaborations are highly appreciated by all technicians as they allow knowledge to be shared between experienced, as well as new, technicians. However, because MCC has service centers in three locations, this knowledge sharing is limited to individual centers.

The information derived from the 'collect equipment measurements' and 'identify and evaluate deviations' steps is produced by the technician with the aid of the diagnostic software. Consequently, the resultant information does not necessarily reflect the day-to-day variations in conditions at the plant, nor the exact positioning and condition of each individual piece of equipment. Initially, most maintenance managers at LKAB believed that the information produced in this way offered a precise representation of the equipment, deviations, and expected future performance. However, the technicians at MCC had a different view of the diagnostic capabilities afforded by the new technology. The MCC developer said: *We must have customer staff present on the floor. They should be our eyes and ears. If a mill sounds abnormal, did it begin this week, or has the oil temperature suddenly increased?* Realizing that there were such discrepancies across the actors involved in the remote diagnostic process, MCC enrolled team managers in training programs about the new technology, and the information it afforded about equipment. In this way, the team managers realized that they still played very important roles as part of the diagnostic process. Hence, rather than adopting a reactive approach, passively waiting for signals to come from the MCC technician, they re-engaged in frequent inspections of equipment as the *in situ* 'eyes and ears' of the diagnostics process.

Discussion

This paper has focused on an examination of the architecture and materiality of IT-enabled services. The objective was to provide insights into how IT is appropriated in and affords business services. To this end, we have distinguished between the mediating and mediated affordances of IT to present an architectural model of IT-enabled services (see Tables 1 and 2). This model illustrates the increasing complexity of managing IT in the context of business services by drawing on theories of information processing, service, and affordance. The workings of the model were illustrated by using it to analyze an IT-enabled remote diagnostics service for machinery and equipment within the mining industry.

The empirical analyses from this study illustrate the different levels of IT-enabled services (Mathiassen and Sørensen 2008). One of the persistent challenges confronting modern businesses is the speed at which they can deliver products and services (Kern et al. 2002). IT-enabled services highlight an important effect of technology, namely the conversion of the skills of an individual, or their organization, into explicit methods and techniques that are then coded into specific IT solutions. To address the variety of circumstances that are associated with this effect, we introduced the architectural model of IT-enabled services. This model unpacks the structure and content of such services and considers a number of associated issues. First, IT-services are enabled by heterogeneous portfolios of IT artifacts. Different IT artifacts afford mediation of information transfer. Thus, designing an artifact where the intended use of the IT artifacts is balanced with their actual use is critical when developing IT-enabled services (Koopman and Hoffman 2003; Norman 1990). Second, IT-enabled services involve a myriad of information services supporting information translation into meaning mediated by signs which have both intended and received meanings (Andersen 1990). Third, IT-enabled services not only depend on the innovative appropriation of IT artifacts or inventive information processing: they depend on both, and the interactions between them. The portfolio of IT artifacts therefore needs to be designed with the information level in mind. The design of the information level needs to be based on the configuration of the artifact level. The management of IT-enabled services is thus a matter of cross-level management rather than simply separating issues between the individual levels. Fourth, the architectural model of IT-enabled services provides particular insight into the unique characteristics of the way in which IT affords social action by introducing the concepts of mediated and mediating affordances. Rather than relying on general notions of how the materiality of IT manifests itself in business services, the model suggests distinguishing between how the materiality of signs allows the sharing of meaning between the involved actors, and how the materiality of artifacts mediates meaning throughout the system. The proposed architectural model of IT-enabled services (see Table 1 and 2), and the application of that model to analyze, in detail, the process by which services are co-produced at LKAB and MCC extends our understanding of how IT-enabled services can be created, indicates the way in which IT is appropriated in this context, and invites new ways of thinking about IT-enabled services. As illustrated in Figure 1, this conceptualization distinguishes between the mediating and mediated affordances of IT and emphasizes how the It-enabled service occurs through recursive intertwining of IT artifacts, signs and human agency. This continual entanglement is conceptualized as two distinct sets of opposites: the mediating affordances are created between the intended and actual usage of IT artifacts; and the mediated affordances between the intended and received meaning of signs.

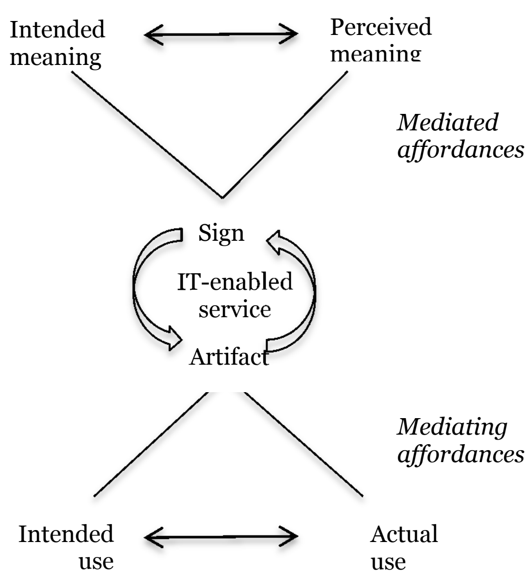


Figure 1. The appropriation of IT in services

Our study contributes to two related areas of literature. First, our research contributes to the theoretical examination of IT-enabled services by expanding the vocabulary to explore, understand and engage in discourse on the subject. Over the last decade, numerous studies have highlighted the transition from goods to services. In particular, the so-called S-D logic (Vargo and Lusch 2004; Vargo and Lusch 2006) is a service-centered alternative to the traditional goods-centered paradigm for understanding economic exchange and value creation. Service logic is 'dominant' in the sense that all businesses are seen as service businesses. Vargo and Lusch (2004) have argued that traditional goods-dominant logic is insufficient for understanding current markets, economic exchange, and marketing. New perspectives that focus on "intangible resources, the co-creation of value, and relationships… are converging to form a new dominant logic for marketing, one in which service provision rather than goods is fundamental to economic exchange." (Vargo and Lusch 2004, p.1). However, their conceptualization does not go far enough. In particular, S-D logic does not sufficiently incorporate the fundamental role of IT. Indeed, even though S-D logic underscores how the service revolution and the information revolution are the flip sides of the same coin, and how IT "has a dramatic effect on the ability of all entities in the value-creation network to collaborate" (Lusch et al. 2007, p 9) little, if anything, has been said about the actual role IT plays in the context of IT-enabled services. The same is true of the literature on IT-enabled services. Barrett and Davidson (2008) discuss the changing nature of services due to the emergence of IT, including storability and the separation of production and consumption of the service. IT has also enabled new self-services, for instance, remote customer order entry and follow-on customer service systems (Lyytinen and Rose 2003). Orlikowski & Schultze (2004) discuss the use of IT as an enabler of automated self-services, where service provision can take place without direct involvement of the service provider. These conceptualizations fail to address the 'IT' in IT-enabled services since they do not pay detailed attention to IT's material features within service performance. Our study adds to this literature by revealing the fundamentals of IT in IT-enabled services. Second, by expanding and demonstrating the set of affordances that arise in IT-enabled services, this study contributes to the literature on materiality. To the best of our knowledge, this has not been accomplished in previous research of the kind we have undertaken. Whilst IS scholars are beginning to pay attention to materiality issues in general, (Leonardi and Barley 2008; Orlikowski and Scott 2008; Zammuto et al. 2007) and the "features that provide opportunities for and constraints on actions" (Leonardi and Barley 2008, p 162) in particular, to date no study has addressed the particular affordances associated with IT. Whilst the literature has explored issues of materiality on a conceptual level (Leonardi 2010; Leonardi and Barley 2008; Orlikowski and Scott 2008), in relation to social-material agency, routines and power (Leonardi and Barley 2008) or in relation to organization (Zammuto et al. 2007), this paper contributes a conceptualization of the unique characteristics of the way in which IT affords social action. This conceptualization distinguishes between the mediating and mediated affordances of IT and emphasizes how the appropriation of IT therefore involves complex interactions between three set of opposites: the involved signs and artifacts, the intended and actual usage of artifacts, and the intended and received meaning of signs.

Conclusions

This paper help address the complex issues involved in IT-enabled services by separating issues between three distinct levels of analysis and supporting detailed consideration of IT appropriation services. As with any research, there are limitations in this work; two in particular require specific mention. First, the case study itself, although illustrative, does not validate the architectural model of IT-enabled services. However, the empirical illustration helped conceptually refine the key concepts in the model. Second, as the proposed model conceptualizes and combines insights from different disciplinary domains, it reflects specific choices. To integrate different perspectives, both the model as a whole (Tables 1 and 2) and the characterization of IT's dual affordances simplify some issues while stressing others.

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