Toward a Science of Service Systems

Value and Symbols

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Economics has accumulated a great body of knowledge about *value*. Building on economics and other disciplines, service science is an emerging transdiscipline. It is the study of value-cocreation phenomena (Spohrer & Maglio, 2010). Value cocreation occurs in the real-world ecology of diverse types of service system entities (e.g., people, families, universities, businesses, and nations). These entities use symbols to reason about the value of knowledge. Like mathematics (quantity relationship proofs) and computer science (efficient representations and algorithms), service science must ultimately embody a set of proven techniques for processing symbols, allowing us to model the world better and to take better actions. In addition, the emergence of service science promises to accelerate the creation of T-shaped Science, Technology, Engineering, and Math (STEM) professionals who are highly adaptive innovators that combine deep problem solving skills in one area with broad communication skills across many areas. This paper casts service science as a transdiscipline based on symbolic processes that adaptively compute the value of interactions among systems.

Introduction: Value and Symbols

Economics, more than any other single scientific discipline, has studied value. For example, economic practice has studied the historical and regional variations in prices of things and of labor. Supply and demand matter. Many price variations can only be understood in terms of national legal and political practices. Within business and family structures, certain activities seem to operate outside the normal price system. Written and unwritten laws and policies matter. For example, the costs of government, health care, education, insurance, electricity,

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communications, transportation, energy, food, water, tobacco, alcohol – really everything – can vary tremendously across social-organizational entities, regions, and time periods. Events and their outcomes matter. For example, positive events, including discovery of natural resources, new uses for materials, new scientific knowledge, technological and business model innovations, or other new reasons for optimism can ignite major growth of jobs and wealth. And negative events, including natural disasters, wars, inflation, depressions, discovery of hazards, and many other factors can wreck havoc on networks of interconnected systems. All this interdependence suggests that rather than resulting from the actions of a single agent or entity, value is necessarily cocreated as a result of interactions of multiple entities. Value cocreation is the primary object of study service science (Spohrer & Maglio, 2010).

Service science aims to improve our ability to create service innovations systematically and reliably. Economists traditionally define the service sector to include government, education, medical and healthcare, banking and insurance, business consulting, information technology services, retail and wholesale, tourism and hospitality, entertainment, transportation and logistics, and legal among others.[1] By the traditional method of economic segmentation, the service sector accounts for most of the world's economic activity (Wolfl, 2005), but is the least studied and least understood part of the economy (Triplett & Bosworth, 2004). Innovation in service is not approached as systematically as innovation in agriculture and manufacturing, which have experienced large productivity and quality gains (Chesbrough & Spohrer, 2006). To remedy this, service science aims to provide theory and practice around service innovation.

In this paper, we argue that the concepts of *value cocreation* and *service system entities* are fundamental to service science. In particular, we define *service as value cocreation phenomena that arise among interacting service system entities* (Maglio & Spohrer, 2010). Division-of-labor is a well-known value-cocreation mechanism. A service system entity is a system that includes one or more people and any number of technologies that adaptively computes and adjusts to the changing value of knowledge. The history of service innovations can be summarized concisely as the evolving repertoire of value-cocreation mechanisms used by service system entities.

Mathematics supports reasoning about what is possible or impossible to know about quantity relationships on the basis of formal logic. Computer science provides estimates of the cost of computing, given specific physical computer architectures and energy costs (e.g., space and time complexity). Computer science depends deeply on both mathematics and physics; as Newell and Simon (1976) argued, the *physical symbol system* is the fundamental abstraction of computer science (see also Newell, 1980). A physical symbol system is a real-world entity that uses symbols to shape its future behavior. Symbols are encoded

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[1] "Development of NAICS" (http:/ /www.census.gov/epcd/www/naicsdev.htm). The North American Industrial Classification System (NAICS), which replaced Standard Industrial Classification (SIC), consists of 20 sectors of which 16 are service related (US Bureau of Census, 2007).

physically, for instance, in transistors, books, neurons, or other materials. Symbols guide both internal behavior and mediate interactions with other entities. Physical symbol systems provide a link between mathematics and physics (Pattee, 2001). Physical symbol systems are fundamental to service science as well: simply put, *service system entities are physical symbol systems*. Without effective symbolic reasoning about value – what we call *processes of valuing* – systematic service innovation would be more akin to evolution than engineering. Of course, value is much more than just symbolic processes of valuing.

To most people, value is how much something is worth – the price another is willing to pay. A price is a value signal squeezed into a short sequence of symbols, an indication of currency and amount (e.g., $5.60, €3.99). Exchange rates and prices are of practical importance. Paying the price creates desired change – it can change who owns something or has access rights to resources. There are many contexts, perspectives, and ways to reason about changes in the world, and ways to create and prevent those changes (von Mises, 1998).

However, value is more than a price or a short sequence of symbols. For example, we all value relationships with other people, and would find it impossible – even socially unacceptable – to reduce the value of a relationship to a price. What is the value of a relationship? Of someone's sense of identity or reputation? Of the way a beautiful sunset makes us feel? Even when we cannot easily or responsibly reduce this sense of valuing something to a price, we still can and often do use symbols to reason about and communicate with others about our *processes of valuing* – if just to say the word "priceless."

In this paper, we introduce our perspective on service science. First, we summarize some of the background literature: what have service research pioneers accomplished, what myths persist and why, how do existing disciplines conceptualize service, and how has service science been emerging most recently?. Second, we describe different types of service systems and the dimensions used to analyze those systems. Third, we discuss the foundations of symbolic processes of valuing. We highlight the evolution of new types of service system entities and the value-cocreation mechanisms that sustain them, focusing specifically on symbol manipulation processes for determining value. Our thesis is that *symbol manipulation is increasingly important as a mechanism for value cocreation*. Finally, we discuss the implications of viewing service systems as entities capable of reasoning about the value of knowledge.

Background: A Complex History

Scholars from economics, marketing, operations, management, engineering, and more – have focused on service over the last two hundred years. We describe a tiny sampling of their works here (summarized in Table 1; for more history, see Berry & Parasuraman, 1993; Brown, Fisk & Bitner, 1994; Vargo & Lusch, 2004a; Gummesson, 2007).

Table 1. Pioneers of service research

What is…	Proposals	References
service?	Non-productive labor	Smith
service?	Competence exchange	Bastiat
optimal exchange?	Comparative advantage	Ricardo
cause of service growth?	Lagging productivity	Clark
result of service growth?	Productivity stagnation	Baumol
model of service systems?	Queuing theory; Systems dynamics; Two-part production system	Riordon; Fitzsimmons; Oliva & Sterman; Mandelbaum; Mills & Moberg
result of service growth?	More tech industrialization	Levitt; Quinn; Zysman
service marketing?	IHIP, 6P's	Judd; Shostack; Berry; Brown; Gronroos, Gummesson
service quality?	GAPS; Linkage; SERVQUAL	Zeithaml & Bitner; Schneider & Bowen; Parasuraman
optimal learning?	Exploration & Exploitation	March
optimal investing?	Profit-chain; Customer equity	Heskett, Sasser, Schlesinger; Rust
service operations?	Customer Contact; Unified Theory; Offering Continuum; Waiting and Queues; Front/Back-Stage	Levitt; Chase; Maister; Larson; Davis; Johnston; Teboul; Sampson; Roth & Menor
B2B service?	Professional relationships	Maister; Bolton; Christopher
service design?	Theater; Hyperreality	Grove & Fisk; Pine & Gilmore; Edvardsson
service innovation?	Customer-focus	Gustafsson & Johnson; Miles; Gadrey & Gallouj; Van Ark, Broersma& Den Hertog; Tidd & Hull
result of service growth?	More innovation	Baumol; Tien & Berg; Gutek
lean techniques?	Lean solutions	Womack & Jones
service?	Rental; perspective on value creation through the lens of the customer	Lovelock & Gummesson; Edvardsson, Gustafsson & Roos
service?	Application of competence; offering	Vargo & Lusch; Gummesson

What is service? Smith (1776/1904) used an example to introduce the distinction between productive and unproductive labor – an instance of service illustrated unproductive labor. According to Smith, the wealth of nations depends on maximizing productive labor and minimizing unproductive labor. Nations that aspire to greater wealth should shift the competencies of their people to activities with the highest profit margins, and ensure those people have the best technology and organizational infrastructure to support them. That is productive labor. Though elsewhere, Smith acknowledged the value and even the necessity of a great many service activities, the damage was done. To this day, service research struggles with the burden of the misconception that service activities are unproductive and ought to be minimized. Creating research-driven service innovation capabilities is an overdue priority for nations and businesses (Baumol, 2002; IfM & IBM, 2008; UK Royal Society, 2009).

What is service? What is optimal exchange? Later political economists provided insights into the nature of value cocreation and exchange. Bastiat (1850/1979) realized that human competence, which he called service, was the foundation for all exchange, even the exchange of material products for money. The best way to understand value was to study service exchange and understand direct and indirect human efforts to apply knowledge for the benefit of others. Ricardo (1817/2004) realized that the optimal performance of productive activities was relative to the range of competencies and opportunities for interactions. Thus, being "relatively less bad at performing a task" can be the basis for value cocreation in a population with diverse competences and needs. Taken together, Bastiat and Ricardo's findings set the stage for a deep appreciation of knowledge-driven value-cocreation interactions between entities. In the short run, advantage may go to those with either superior competences or superior comparative advantages. In the long run, advantage may go to entities that can learn fastest. When it comes to value cocreation, knowledge is king – primarily knowledge of how to do things (competencies) and knowledge of others (their relative competencies and needs), and secondarily knowledge to create new competencies and relationships.

Why service growth? Clark (1940/1957) provided a first mapping of national competences – their relative strengths in agriculture, manufacturing, and service. Developed nations were using technology to dramatically improve productivity (competences) related to agricultural and manufactured goods. As their populations grew, a relatively larger percentage of the population was finding its comparative advantage in other areas of the economy, broadly labeled the service sector. Competences inside family groups were beginning to be externalized as productivity grew in agriculture and manufacturing. He hypothesized that national labor pools would shift to areas of economic activity with lagging productivity growth rates. Nations compete by increasing productivity and shifting labor to areas of comparative advantage.

What is the ultimate result of service growth? As Clark predicted, because the US was leading the world in agricultural and manufacturing productivity growth, export markets saturated, and workers in those two areas shrank to less than fifty percent. Baumol explained why the salaries associated with jobs that did not experience large productivity increases also rose (Baumol & Bowen, 1966). "Baumol's Cost Disease," not unlike Smith's unproductive labor example, became the source of a misconception that large service sectors were bad.

How have service systems been modeled? Mathematical and computer models of service systems mark a turning point in the scientific study of service. One of the first characteristics of service systems to be modeled was the stochastic nature of the capacity limits under variable demand. Riordan (1962) used queuing theory to analyze telephone switching networks to develop a theory of stochastic service systems. Queuing theory is used to analyze other types of service systems, ranging from ambulance emergency response to call centers (e.g., Fitzsimmons & Fitzsimmons, 2007; Mandelbaum and Zeltyn, 2008). Mills and Moberg (1982) used a two-component model of service systems with a technical component akin to a manufacturing core that could be sealed off and standardized, but with a customer interface component required to deal with uncertainty and variability of diverse customers. Oliva and Sterman (2001) developed a systems dynamics approach to model the erosion of quality in service businesses when hiring lags behind demand spikes (see also Oliva & Sterman, this volume).

How will technology influence the evolution of service productivity? Levitt (1976) introduced the concept of industrialization of service via technology. Quinn and Paquette (1990) showed that technology would provide the service sector with a path to continuous productivity improvements, and that standardized technology-based service components would provide an architecture for new service development. Zysman (2006) referred to the algorith mic revolution, which puts service productivity on an ICT-based improvement curve.

How is service marketing different? Economists measured the growth of the service sector and the concerns about productivity stagnation. Meanwhile, academics in business schools took note and outlined managerial implications. Marketing was first. Judd (1964) argued for a better definition of services. A market transaction that does not transfer ownership has three main categories: rented goods services, improvement of owned goods services, and non-goods services. Shostack (1977) argued that service marketing should break free of product marketing. Shostack's writings and speeches helped condense some of the thoughts in the air at the time, suggesting that services were intangible, heterogeneous, inseparable, and perishable (the IHIP characteristics),[2] and that marketing should take account of 6 P's – Product, Price, Place, Promotion, People, and Process. In Europe, Gronroos (1977) and Gummensson (1977) were also

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[2] "Philosophical contributions from three centuries provided a set of 'characteristics' of services that have now been claimed to distinguish them from goods. The most famous are intangibility, heterogeneity, inseparability and perishability, now known as the IHIPs. In Scotland, Adam Smith (1723-1790) discussed perishability of services; in France, Jean-Baptiste Say (1767-1832) introduced intangibility (immateriality) and inseparability; and in England Joan Robinson (1903-1983) brought in heterogeneity. Services seem then to have been dropped from the economics agenda, but the interest was revived in management and marketing. The earliest marketing references for these characteristics appeared in the beginning of the 1960s" (Gummesson, 2007).

making the case. Berry and Parasuraman (1993) and Brown, Fisk, and Bitner (1994) documented the rise of service marketing.

How is service quality different? Service marketing brought a focus to improving service quality. SERVQUAL (Parasuraman, Zeithhaml & Berry, 1985), the GAPS Model (Zeithaml, Bitner, Gremler, 2006), and the Linkage Model (Schneider & Bowen, 1993) provided multiple angles on service quality. The human element – both customers and employees – is prominent in all three (see also Schneider & Bowen, this volume; Bitner, Zeithaml & Gremler, this volume).

What is optimal learning? Like optimal exchange, optimal learning is an important foundation for a science of service systems – the ability to change competences and relationships. March (1991) introduced the notions of exploration and exploitation in organizational learning. If an environment is changing rapidly, an entity capable of learning (e.g., individual or organization) risks extinction if it does not adapt. The entity ought to invest resources in exploration to maintain its fit (competences and relationships). If the environment is very stable, an entity may do well simply exploiting existing behavioral patterns (competences and relationships). An optimal learning rate is a function of the environmental change rate. Exploration attempts to innovate with no guarantee of success. Menor, Tatikonda, and Sampson (2002) examined new service development in the context of exploitation and exploration.

What is optimal investing? Heskett, Sasser, and Schlesinger (1997) described the service-profit chain, demonstrating a direct and strong relationship between profit, growth, customer loyalty, customer satisfaction, the value of goods and services delivered to customers, as well as employee capabilities, satisfaction, loyalty, and productivity (see also Heskett and Sasser in this volume). Rust, Zeithhaml, and Lemon (2000) suggested investing with a keen sense of “total customer lifetime value” allows a firm to make bold and successful strategies pay off (see also Rust & Bhalla, this volume).

What are service operations? About the same time that service marketing was taking root in business schools, service operations was also taking root. Levitt (1972) advocated a production-line approach to service – as well as the notion of front and back stage operations, later developed further by Teboul (2006). Chase (1981) advanced a customer-contact theory to estimate the potential for improving service productivity in service systems. The greater a provider’s need for customer contact and the more diverse the customers, the less opportunity for standardization and productivity improvements (see also Chase, this volume). Johnston (1989) even proposed that the customer be viewed as an employee, in need of training to improve productivity and quality. Going beyond mathematical models of service, Maister (1985) explored the psychology of waiting in queues. Larson (1987) examined the implications for social justice. Davis (1991) examined queues, and the way customer interaction in service processes can lead to trade-offs that managers of service operations must make in service system design. Roth and Menor (2003) distinguished the unique methods and research agenda of service operations management that combines quantitative and qualitative models. Sampson and Froehle (2006) proposed a unified service theory to understand processes with customer input (see also Sampson, this volume).

What is B2B service? The majority of service research has explored business-to-consumer (B2C) interactions and processes. Business-to-business (B2B) service was explored by Maister (1993) in the context of professional service firms. Bolton, Smith, and Wagner (2003) further explored factors that strike the right balance in successful relationships in complex B2B contexts. Christopher, Payne, and Ballantyne (1991) provided a broad perspective on the practice of relationship marketing. The nature of complex network relationships is an important topic in B2B service (Gummesson, 2007; Vargo, 2009). Building off traditional supply chain management, the notions of service value chain management and globally integrated enterprise are emerging priorities (Palmisano, 2006).

What is service design? Grove and Fisk (1992) conceived the service experience as theater, and service design as akin to staging a production. Pine and Gilmore (1999) described an experience economy in which service providers compete on the design of customer experiences. Edvardsson, Enquist, and Johnston (2005) explored the future of service design, envisioning hyperreality simulations to provide customers with a "try before you buy" capability.

What is service innovation? The increasing importance of service innovation has been well documented in recent years (Gadrey & Gallouj, 2002; Van Ark, Broersma, den Hertog, 2003; Tidd & Hull, 2003; Gustafsson & Johnson, 2003; Miles, 2006, 2008; Spath & Fähnrich, 2007). Though many sophisticated service innovation models have been developed and contrasted with product and process innovation models, one common denominator comes through – service innovation is necessarily customer-focused. Customers change and service innovation must keep up to reduce customer costs while working to increase customer value. Customer competences (as in self-service models) and relationships (access to other experts or customers) constantly change (see also Miles, this volume).

How are lean techniques being applied to service? Womack and Jones (2005) observed that consumption is often hard work for the consumer and is unpaid work to boot. The principles expressed in the voice of the customer are "Solve my problem completely. Don't waste my time. Provide exactly what I want. Deliver value where I want it. Supply value when I want it. Reduce the number of decisions I must make to solve my problems."

What is the ultimate result of service growth? Baumol (2002) developed a new sector productivity model. As long as the research sector ("the queen of the service sector") enjoys even a small increase in productivity over time, all other sectors that depend on scientific research (which today is almost all sectors) can realize continuous productivity gains from innovation. Baumol's disease was cured (Triplett & Bosworth, 2003). Tien and Berg (2007) developed a calculus for service innovation that links productivity gains to increasing knowledge about customers. Technology-enabled mass customization will make all sectors more like custom service (e.g., shoes and clothing personalized, medicines and foods personalized, etc.). However, Gutek (1995) warned that a shift from personal relationships to high productivity impersonal interactions may have unintended consequences.

What is service? Lovelock and Gummesson (2004) exposed the problems with IHIP and other models, and proposed a rental or resource access model of value cocreation. Edvardsson, Gustafsson, and Roos (2005) reexamined the problems with existing definitions and suggested that service is best conceptualized as a perspective on value creation through the lens of the customer. Gummesson (2007) suggested that from a provider perspective, the word “offerings” can replace both “goods” and “services”, and along with Vargo and Lusch (2004), noted that “service” (in the singular) is the core concept underlying both “goods” and “services”. A provider offers a value proposition (the offering) to the customer, but value *actualization* occurs in a separate customer process. Thus value is the outcome of cocreation interactions between providers (with offerings) and customers (with actualizations). Gummesson advocated going beyond the customer-provider dyad to consider, complex adaptive networks of customer-provider entities and their diverse offerings and actualizations (see also Gummesson, this volume).

What is service? Vargo and Lusch (2004) turned the page on the early days of service research, in which goods and services were contrasted, by introducing *service-dominant logic* (see also Vargo, Lusch & Akaka, this volume). As mentioned, most people had considered services to be an inferior form of goods, but one that was unfortunately growing like an unsightly weed on developed economies, stagnating needed productivity growth, interfering with efforts to remain globally competitive, causing wage inflation, and lowering the quality of jobs and thereby quality of life in developed nations. Service-dominant logic, like Bastiat (1850/1979), viewed service-for-service exchange as the fundamental driver of the economy, and goods-dominant logic as hiding the fundamental nature of exchange. Vargo and Lusch (2004) suggested defining service as a type of process, specifically the process of one or more entities applying competences (knowledge, resources) for the benefit of another. The service-dominant logic view established a foundation on which to build a science of service system entities and their value-cocreation interactions (Spohrer & Maglio, 2010).

Myth Busting

Unfortunately, myths or misconceptions about service persist. In this section, we bust them (see Table 2 for summary).

Table 2. Persistent myths about service

Myth	Reality	Reference(s)
Productivity is stagnant in service sector	Augmenting human and organizational performance with technology innovations, making hidden information accessible, or incentive alignment strategies are three of many ways to increases service sector performance	Baumol
Service sector jobs are low skill and low wage	Service sector leads in the creation of new high skill and high pay jobs	Herzenberg, Alic, Wial; Levy & Murnane
Service sector is all labor, and little technology	Service sector is extremely knowledge and technology intensive	Royal Society Report
STEM (Science Technology Engineering and Math) graduates cannot find good jobs in the service sector	Service sector hires most STEM graduates in developed economies to improve and innovate service	Royal Society Report
Service quality is subjective and resists systematic improvement	Service quality can be scientifically studied and improved; Intimately, connected to accurate service productivity measurement	Schneider & Bowen; Gadrey & Gallouj
Service sector is too diverse to be studied systematically	There are just four broad types of service based on resource types; Service transforms entities or their property	Spohrer & Maglio; Hill

Productivity is stagnant in the service sector. Baumol (2002) put to rest this myth. His revised sector model showed that *scientific research productivity* is the key, along with new tools of science – from better computers to better gene sequencing equipment. Of course, national economic statistics validate just this reality (Triplett & Bosworth, 2003). Scientific advances include: augmenting human and organizational performance with technology (e.g., bar code scanners at retail check out, self service retail check out), making hidden information accessible and incentive alignment strategies (e.g., electricity rate schedules visible at time of use on appliances). So why does this myth persist? Perhaps most people's view of the service sector is of waitresses, chamber maids, retail clerks, and trash collectors. Because these jobs do not seem to be changing much, people over generalize. This is likely to change in the coming decades. For example, robotic trash vehicles are already working in prototypes.

Service sector jobs are low skill and low wage jobs. Herzenberg, Alic, and Wial (2000) showed high skill and high wage jobs are growing fastest in the service sector. A comprehensive view of the full range of service sector jobs includes professional, scientific, technical jobs. Levy and Murnane (2004) also demonstrated that computers and other types of information and communications technologies (ICT) create demand for more expert thinking and complex communications skills in the workplace. So why does the myth persist? With so few jobs today in agriculture and manufacturing sectors, perhaps people are romanticizing old types of jobs. Or perhaps if one is a professor, an executive, a doctor, or politician, it is hard to recognize one is in a service sector job. This is likely to change as knowledge-intensive service activities increase and people begin to associate knowledge workers with the predominant service sector jobs.

Service sector is all labor and little technology. The UK Royal Society (2009) provided a clear account of the transformative nature of technology in major service innovations. From internet-based to smart phone-based businesses and from financial services to health care, many aspects of life are becoming instrumented, interconnected, and intelligent to support improved quality of service. Technology allows new service offerings to scale up faster and reach more customers in less time. So why does the myth persist? Perhaps the growth in public sector jobs, government, public safety, healthcare, and education is what is top of mind for most people. We see the number of teachers, police officers, fire fighters, nurses, or public service agents increasing or stable, and do not see the increasing use of technology needed to perform these jobs well.

Science, Technology, Engineering, and Math (STEM) graduates cannot find good jobs in the service sector. The UK Royal Society (2009) report confirmed that 82% of STEM graduates in the UK found jobs in the service sector, and most contribute to continuous innovation there. So why does the myth persist? Many of the routine everyday service sector jobs that most of us are likely to encounter (waitress, retail clerk, etc.) do not require college degrees. Professionals simply do not see themselves as service sector workers.

Service quality is subjective and resists systematic improvement. Schneider and Bowen (1993) and Gadrey and Gallouj (2002) provided evidence that service quality can be the focus of scientific investigations and improvement. In fact, service quality and service productivity are often intimately linked, as when Automatic Teller Machines (ATM) were introduced and quickly revolutionized what most people do when they visit a bank – they interact with an ATM, when and where they want. So why does the myth persist? One reason is that people's expectations of quality are continually rising.

Service sector is too diverse to be studied systematically. Hill's (1977) view of service was transformation of an entity or its possessions (economic transactions that do not change ownership). Spohrer and Maglio (2010) suggested that just four types of resources are transformed. So why does the myth persist? Perhaps the relatively primitive way in which new service systems and value propositions are designed provides part of the answer. Methodologies for creating value propositions are becoming more sophisticated (Anderson, Kumar, & Narus, 2007). When a computer-aided design (CAD) tool exists to create new designs from building blocks systematically, this myth will begin to fad.

Many Disciplines, Many Views of Service

A wide range of academic disciplines have developed views of service. This is one indication that service science, as an emerging transdiscipline, can ultimately make a contribution to many other disciplines (see Table 3 for a summary).

Table 3. Disciplinary views of "service"

Discipline	Focus	References
Economics	Service is a distinct type of exchange, a category for counting output, jobs, businesses, exports, etc.; A service is a change in the condition of a person or a good belonging to some economic entity, brought about as a result of some other economic entity	Triplett; Hill
Marketing	Service is a distinct type of exchange, delivered by a distinct type of process, often characterized by customized human interactions ("moments of truth"); Service is the application of competence for the benefit of another	Shostack; Bitner & Brown; Carlzon; Vargo & Lusch
Operations	Service is a distinct type of production process, characterized by dependence on customer inputs	Chase; Sampson
Industrial & Systems Engineering	Service systems and networks present a distinct type of engineering problem, characterized by customer variability (including processing times and queues)	Riordan; Mandelbaum
Operations Research	Service systems and networks present a distinct modeling and optimization problems, characterized by dynamic and stochastic capacity and demand	Thomas & Griffin; Dietrich & Harrison
Computer Science	Service is an abstraction for network-accessible capabilities with unique discovery, composition, and modeling challenges	Zhang; Seth; Endrei

Information Systems	Service systems can be improved using properly managed information system Service systems are work systems	Rai & Sambamurthy; Alter
Social Sciences	Service systems are related to socio-technical systems, as well as systems engineering models of enterprises	Rouse & Baba
Behavioral Sciences	Service is an experience, shaped by many factors including waiting in queues and customer expectations	Chase & Dasu; Maister

Economics. As exemplified in Triplett and Bosworth's (2004) analysis, service can be viewed as a distinct type of exchange, a category for counting and analyzing jobs, businesses, exports, as well as inputs and outputs (productivity). Unsatisfied with a negative definition of service as an exchange that does not involve transfer of physical goods, Hill (1977) proposed that a service is a change in the condition of a person, or a good belonging to some economic entity, brought about as a result of some other economic entity, with the approval of the first person or economic entity. From a service science perspective, Hill's definition begins to place emphasis on *interaction* of economic entities.

Economists measure and count entities and their exchanges. Money-for-things-type exchanges make sense when counting in the agriculture and manufacturing sectors. Money-for-labor-promises-etc-type exchanges make sense when counting in the service sector. Economists measure that a smaller percentage of the total exchanges are of the money-for-things type. Thus, from the traditional economics perspective, the growth of the service sector results. Measurement can get complicated because of exceptions (e.g., restaurant and retail are service providers that transfer ownership of goods), diverse types of entities (e.g., people, businesses, and nations), and aggregation methods (e.g., sectors, markets). In an age of increased outsourcing, economists noticed that when a manufacturing firm outsources parts of its business (e.g., product design) – even though the same people may be doing the same work, but now part of a new separate entity – the statistics shift to count the jobs and revenue in the service sector rather than as part of the manufacturing sector. Understandably, this creates some amount of cognitive dissonance, and the sense that perhaps the growth of the service sector is more illusion than reality, especially when sectoral counting is so sensitive to insourcing and outsourcing decisions of businesses (Triplett & Bosworth, 2003).

Bastiat (1850/1977) and Vargo and Lusch (2004) note that "things" result from skilled labor (harvesting or manufacturing requires the application of knowledge), and so argue that "service" is more fundamental than things. They claim the basis of all economic exchange is *service for service exchange*, which was much clearer before mass production and money, when the barter of custom-made offerings was the norm. The first foundational proposition of service dominant logic is that service is the fundamental basis of exchange.

As society enters the age of wikinomics (Tapscott & Williams, 2006), exchange of money for labor is not always present. Clark (1940/1957) noted the reverse trend that value created inside families was shifting to external markets that involved paying others for family-related service (e.g., child care, eating out). Service system entities are complex and dynamic (insourcing and outsourcing), and the nature of value cocreation itself is often linked to identity and reputation (wikinomics, peer production).

Marketing. Marketing as a function in business firms provides customer insights, both for existing customers and potential future customers. These insights are used by other functions (strategy, communications, production, and delivery) to improve decision making. Service is a distinct type of exchange (Judd 1964; Shostack 1977), delivered by a distinct type of process (Bitner & Brown 2006), often characterized by customized human interactions or "moments of truth" with customers (Carlzon 1987). Service is the application of competence for the benefit of another (Vargo & Lusch, 2004).

Operations. Service is a process, characterized by dependence on customer inputs (Chase 1981; Sampson & Froehle 2006). The customer input can range from a little to a lot. For example, citizens of a society confer tacit agreement to comply with laws and standard operating procedures – a sometimes small individual input, though in aggregate necessary to the proper functioning of society. At the other end of the spectrum, a person working with a doctor may be required to provide not only his or her body for surgery, but also required to eat, exercise, and make necessary financial arrangements to receive service. Self-service procedures that make use of a provider's infrastructure may require even more serious effort and customer inputs. Complex business to business (B2B) or business to government (B2G) service offerings may require hundreds or even thousands of people to interact.

Industrial and Systems Engineering. Service systems and networks present a distinct type of engineering problem characterized by customer variability (Riordan 1962; Mandelbaum & Zeltyn, 2008). By making simplifying assumptions, modeling entities as stochastic service systems becomes possible. These types of models provide needed formalisms for engineers to build simulation models of service networks, and measure performance under diverse operating assumptions and constraints. Engineers build computer-aided design tools to manage service component libraries (Sanz, Nyak & Becker, 2006).

Operations Research. Service systems and networks present a distinct type of modeling and optimization problem (Thomas & Griffin, 1996; Dietrich & Harrison, 2006). Often real-time sensors allow analytics and statistical learning methods to be applied to continuously adapt and tune performance of models. Statistical control theory, game theory, and mechanism design theory may also be used to increase the sophistication of the mathematical models to address dynamic environments, human psychology, and other factors.

Computer Science. Service is an abstraction for network-accessible capabilities with unique discovery, composition, and modeling challenges (Zhang, 2007; Sheth et. al, 2006; Endrei et. al, 2004). Computer science can be used to create software components to automate service, as well as to improve self-service. When these components are network accessible and composable, web services can allow re-use of simple building blocks. In addition, computer science approaches to modeling business and societal enterprises (with service-oriented architectures) as well as use-case models can enable new service design, and planning of work transformation or enterprise transformation projects. Service-oriented architecture (SOA) refers to networks of loosely coupled, communicating service components.

Information Systems. Information systems are service systems; service systems are work systems (Rai & Sambamurthy, 2006; Checkland & Howell, 1998/2005; Alter, 2008). If improving the performance of a service system is a priority, then that system will likely become instrumented, interconnected, and intelligent (partial algorithmic control) using information systems. Information systems create both an engineering challenge and a management challenge, as they require technology upgrades and on-going investment. The system must work as designed from functional, regulatory, and business model perspectives.

Social Sciences. Service systems are closely related to socio-technical systems and systems engineering models of enterprises (Rouse & Baba, 2006). Social systems are broader than service systems, and include social insects for example. Advanced socio-technical systems, on the other hand, are nearly isomorphic with the concept of service systems, as they require symbolic processes of valuing. Service science borrows from the social sciences, but with the premise that symbolic value-cocreation mechanisms explain change. Informal service system entities (language), formal service system entities (writing), and globally integrated formal service system entities (digitization) are three evolutionary stages (Spohrer & Maglio, 2010). At each stage, value cocreation potential increases through better use of symbol processing in people and technology, allowing improved coordination. Another relative of service science is coordination theory. Coordination theory draws from computer science, organization theory, operations research, economics, linguistics, and psychology. Coordination is the process of managing dependencies among activities (Malone & Crowston, 1994).

Behavioral Sciences. Service experience is shaped by factors, including waiting in queues and customer expectations (Maister, 1985; Chase & Dasu, 2001). Psychology matters because people are the primary source of variability in service design. Individual differences are a source of variability that designers struggle to accommodate. Nevertheless, in some ways, people are both predictably rational and predictably irrational. Behavioral sciences, including experimental economics, have useful results to improve value-cocreation mechanism design (Ariely, 2008).

Emergence of Service Science

Recently, a new science of modern service, which aims to tie together disciplinary views in a theoretically coherent and practically important way, has begun to emerge (see Table 4 for a small sampling). Of course, this whole volume is a testament to the emergence of service science and the integration challenge.

Table 4. Some recent thought related to service science

What is …?	Proposals	References
service?	Value creation systems; co-production; value constellations	Normann & Ramirez; Normann; Wright
a science of service?	Involves technology to improve productivity and quality for B2B	IBM
proper perspective on service?	Service-Dominant Logic	Vargo & Lusch
Why under-studied?	Too many myths, too few facts	Chesbrough & Spohrer
Why now?	Economic importance; physical, information, social progression in science	Maglio, Kreulen, Srinivasan & Spohrer
a service system?	Dynamic resource configurations	Spohrer, Maglio, Bailey & Gruhl
work evolution in service?	Z-model	Spohrer & Maglio
needed to make progress?	National service innovation roadmaps reports	IfM & IBM
complexity of service networks?	Direct and indirect actors	Basole & Rouse
progress in education?	SSME and related programs	Hefley & Murphy
service entity interaction?	ISPAR	Maglio, Vargo, Caswell & Spohrer
value?	value in use	Vargo, Maglio, Akaka
needed discipline integration architecture?	Time, stakeholder/measures, resources/access-rights	Spohrer & Kwan
service system learning?	Run-Transform-Innovate	Spohrer & Maglio
service system scaling?	Digitally Connected Scaling	Hsu
the problem with local optimization?	Does not lead to global optimization	Ricketts
service system design?	Transformative technologies	Glushko; UK Royal Society
response to disasters?	Humanitarian service science	Haselkorn
response to globalization?	Intercultural service systems	Medina-Borja

What is service? The essence of service is value creation (Normann & Ramirez, 1993; Normann, 2001). Networked entities alternately liquefy and solidify access to resources in new higher density constellations that create more value. Wright (2000) described human history as "evolving better *non-zero sum games*" – games that do not simply shift value (i.e., win-lose) but create more than they consume (i.e., win-win or value cocreation) – the intended meaning of Smith's "productive labor."

Could there be a science of service? IBM (2004) reported on a workshop in which academics explored the possibility of collaborating on building a science of modern service. The conclusion was positive, with a recognition that foundations had been put in place by pioneers from multiple academic disciplines. However, much work remained, especially in the area of business-to-business (B2B) service. Creating a science of service would require shifting, aligning, and integrating knowledge from existing areas, as well as creating new tools and knowledge that organizations might consider proprietary. Science is the agreed upon methods and standards of rigor used by a community to develop a body of knowledge that accounts for observable phenomenon with conceptual frameworks, models, theories, and laws that can be both empirically tested and applied within a world view or paradigm (Kuhn, 1962). Getting a unified community to agree on what service science is, and what its top research challenge should be, was acknowledged to be non-trivial.

What would be a proper perspective or worldview on which to base a science of service? Vargo and Lusch (2004) captured the debate that was taking place in many businesses, especially manufacturing firms with rapidly growing service revenues. A growing realization was that goods-dominant logic (GDL) and service-dominant-logic (SDL) made different assumptions about creating and measuring *value*. SDL established a worldview for thinking about service that stands in sharp contrast to GDL, which guides most people's thinking about value and economic exchange today (Vargo & Lusch, 2004, 2008). SDL defines service as the application of competence (knowledge) for the benefit of another. SDL's first foundational proposition is that all human economic exchange is service-for-service exchange. Goods can only be harvested or manufactured through the application of competence. Most people see the value in the goods, rather than appreciating the true source, the application of competence.

Why has service been understudied? Chesbrough and Spohrer (2006) argued that given the economic importance of the service sector, as well as two decades of US National Academy of Engineering Reports (2003) confirming this, that the area remains understudied. In spite of evidence, the persistence of myths and conceptual confusions, with no unified service science community to refute them, has been at the root problem. In fact, disciplinary approaches to service might be working at cross purposes, maintaining the conceptual confusions and causing policy makers and government funding agencies to be justifiably cautious. Chesbrough and Spohrer's proposed service science research manifesto was a starting point to unify researchers on a set of research challenges, and begin to overcome the myths with demonstrable progress. They also pointed to the emergence of computer science, over fifty years earlier, which despite many challenges and delays, was ultimately established as a new discipline. Significant progress was made once researchers and practitioners aligned around a common research agenda. For service science, they suggested a research agenda with a focus on provider-customer interactions and provider-customer knowledge-sharing enabled by ICT advances.

Why now? If the economic statistics argument were the main driver, service science might have emerged at least two decades earlier, when National Academy reports were advocating more service research and technology to industrialize service components (Guile & Quinn, 1988). Maglio et. al. (2006) went beyond the normal economic statistics, arguing that in the 1800's the study of physical work (steam engines) matured into a science, in the 1900's computational work (computers), and the 2000's societal work (digital networks) would likely mature into a science. Hsu (2009) argued that digitally connected scaling creates the opportunity for modern service science. Statistics suggest the need, and digital networks create the opportunity for value cocreation mechanisms to become more widespread and more instrumented for scientific study (Berners-Lee et al, 2006; Foster, 2005).

What is a service system entity? Service is value-cocreation, that is, beneficial changes that result from communication, planning, or other purposeful interactions between distinct entities (Spohrer & Maglio, 2010). For our purposes, an entity capable of intentional value-cocreation interactions can be viewed as a service system entity (Spohrer, Maglio, Gruhl & Bailey, 2007; Maglio, Vargo, Caswell & Spohrer, 2009). They can be thought of as dynamic configurations of resources that include one or more persons, and evolve complex structure and interaction patterns (Spohrer & Maglio, 2010). A service ecology is a population of such entities that, as a whole, are better off working together than working alone (Vargo, Maglio & Akaka, 2008; Spohrer & Maglio, 2010). So our object of study is value-cocreation mechanisms, our basic abstraction is the service system entity, and our ultimate goal is to develop methods and theories that can be used to explain and improve our service ecology (Spohrer & Maglio, 2010).

What is the nature of work evolution in service? Spohrer and Maglio (2008) proposed a Z-model of work evolution for maturing service offerings. First, an offering is delivered by people, often highly skilled and specialized. Second, people using technology tools deliver the offering. Third, standardization and migration to the lowest cost labor geography occurs. Fourth, an automated component becomes a building block for higher value offerings. For example, (a) customer technical support calls for a start up may be handled by the director of engineering, (b) later, employees with a Frequently Asked Questions (FAQ) tool may answer the calls, (c) still later, an employee of a call center outsourcing business may answer, and (d) finally, an automated speech recognition system may be used (self service). The customer technical support example helps illustrate the way a service system may adapt to the changing value of knowledge in the system: value-add knowledge in people, shared information, organizations, and technology.

What is needed to make progress? IfM and IBM (2008) called for nations to create *service innovation roadmaps* to accelerate investment in service research and education, specifically, for a doubling of investment before 2015. As reported in Spohrer, Ren and Gregory (this volume) nations are using such roadmaps to guide investment on a shared agenda to accelerate service innovation.

What is the relative complexity of different service networks for different industries? Basole and Rouse (2007; see also Rouse & Basole in this volume) provided a framework for modeling and calculating a measure of the complexity of different configurations and structures of service networks. Certain configurations allow innovations to spread rapidly and other configurations hinder the spread of innovations to customers. In general, public sector networks have higher complexity and lower rates of innovation spreading than private sector networks.

What progress is occurring in educating students to be prepared for a productive life in a modern service economy? Hefley and Murphy (2008) collected papers and perspectives from one of the largest events ever to focus on education for a 21st century service economy. Progress in the separate discipline silos, alignment (consensus on core concepts) and integration (common models and tools) were discussed.

How do service system entities interact? Not all interactions result in value cocreation. Maglio, Vargo, Caswell, and Spohrer (2009) presented the Interact-Service-Propose-Agree-Realize (ISPAR) model of entity interactions. Of the ten possible outcomes described, less than fifty percent result in value cocreation. However, the others may contribute value by accelerating learning curves and improving resilience.

What is value? Vargo, Maglio, and Akaka (2008) provided a service science and service-dominant logic perspective on value and value cocreation. They argued that value is fundamentally derived and determined in use – the integration and application of resources in a specific context – rather than in exchange – embedded in firm output and captured by price. The current paper builds on these ideas by introducing the concept of *processes of valuing* as one way in which entities can estimate potential for value-in-use.

What is an architectural framework for discipline alignment and integration? Spohrer and Kwan (2008) and Spohrer and Maglio (2010) provided an architecture to integrate disparate disciplines into a service science transdiscipline. The architecture links disciplines to a time dimension (past, present, and future), stakeholder and measures dimensions (customer, quality; provide, productivity; authority, compliance; competitor, sustainable innovation), and resource and access rights dimensions (people, privileged access; technology, owned-outright; organizations, leased-contracted; shared information, shared access).

What is service system learning? Building on March's (1991) exploration and exploitation model of organizational learning systems, Spohrer and Maglio (2010) developed a run-transform-innovate model of service system learning. Run-transform-innovate is terminology borrowed from IBM's CIO office, and represents best practice decision making when investing for organizational change (Sanford, 2006). Run is budget for operate and maintain. Transform is budget to copy best practices. Innovate is budget to invent new best practices. Innovate is often the riskiest, but also has the most potential for reward.

What is service system scaling? Hsu (2009) presented a theory of digitally connected scaling. Franchising is a scaling model that was used in the past. Digitally connected scaling overcomes limitations of franchising and other scaling models that require providers to establish local operations in geographies.

What is the problem with local optimization? Ricketts (2007) presented a central challenge in service system and network optimization, namely local optimization does not often lead to global optimization. In fact, local optimization is likely to increase the demand on the most bottlenecked component. Ricketts showed how to apply the Theory of Constraints to professional service businesses that depend on human knowledge and skills. This work is an excellent example of reworking a manufacturing-oriented methodology to become relevant for service businesses.

What is service system design? Glushko's framework (this volume) provides a approach to information-intensive service system design (see also Glushko & Tabas, 2009). The focus is on the information required and the responsibility of the providers and customers. The result is substitutable and combinable building blocks of service systems for different service contexts. Increasingly service design depends on STEM graduates because of the growing sophistication of service systems (UK Royal Society, 2009).

What is a service science response to disasters? Haselkorn (2008) developed the area of humanitarian service science. When a disaster occurs, such as a hurricane or earthquake, thousands of lives can plunged into turmoil and chaos. Every basic service is disrupted and quality of life suffers. How to increase the speed of rebuilding is an important area of research. Haselkorn's work demonstrates the importance of using simulation technology to plan and prepare for disasters, and accelerate rebuilding. This is an emerging frontier in engineering research that explores how to effectively design, evaluate, and predict the behavior of market-based service systems extended into non-profit areas.

What is a service science response to globalization? Medina-Borja (2008) developed the area of intercultural service science. Service delivery varies from New Delhi to New York. Whenever the provider and customer are of different cultures anomalies may arise. Outcomes are influenced by the cultural and social background of those involved. Intercultural service science will be an increasingly important source of insights to inform service system design in the next decade.

We could have chosen from hundreds of other recent publications on service systems, service networks, and service science. A more comprehensive survey is needed to do justice to the explosion of thinking in this emerging area. Nevertheless, this snapshot shows the growing importance of this area.

Complex Dimensions of Service Systems

There is a great variety of service systems – value cocreation arrangements among distinct entities. As mentioned, a service system entity is a value-cocreation configuration of people, technology, other internal and external service system entities, and shared information (Spohrer & Maglio, 2010). This recursive definition highlights that fact that they have internal structure and external structure in which value is cocreated directly or indirectly with other service system entities. Individuals, families, firms, nations, and economies are all instances of service system entities. In this section, we describe just a few kinds of service system entities and their value-cocreation relationships to demonstrate some of the complexity inherent in understanding, improving, and innovating in service systems in the real world (see Table 5 for a summary).

Table 5. Examples of service system entities and their dimensions

Entities	Dimensions	References
Universities	People, organizations, information	Maglio, Kreulen, Srinivasan & Spohrer; Spohrer, Maglio, Bailey & Gruhl
IT service providers	People, technology, organizations, business	Blomberg; Pinhanez; Maglio, Kreulen, Srinivasan & Spohrer; Spohrer, Maglio, Bailey & Gruhl
Contact centers	People, technology, information	Cheng, Krishna, Boyette, & Bethea; Maglio, Kreulen, Srinivasan & Spohrer
Banking services	People, processes, information, organizations, business	Alter; Oliva & Sterman
Internal process transformations	Organizations, processes, technology, business	Krishna, Bailey & Lelescu,

Universities. Universities are service system entities (Maglio et al, 2006; Spohrer et al, 2007). They aim to transform student knowledge. Typically, the cost is not borne by students alone; rather, universities are supported by a number of sources, including individual, corporate, non-profit, and government sponsors. Although potentially beneficial to everyone involved, this economic arrangement results in a service equation that is much more complex than that of a single, unambiguous service client. Rather than managing a single value-cocreation relationship, universities manage relationships among multiple clients and partners, who may or may not know or care about the others. Expectations and results vary. The student is likely to judge quality on qualitative measures, whereas a corporate or government supporter might rely more on collective quantitative measures, such as standardized performance measures and number of graduates.

IT service providers. An IT service provider offers to take over the operation and maintenance of client's IT investments, and to do it better and cheaper than the client–IT outsourcing (see also Maglio et al, 2006; Spohrer et al, 2007). The provider aims to improve the efficiency of client IT operations, reducing cost over time by applying unique skills, experience, and capabilities. The size and nature of outsourcing service arrangements vary from multi-billion dollar mega-deals, in which the service provider takes over all IT investments of a large company, to smaller deals in which the provider agrees to just take over a single functional area, such as help-desk operations or web-server operations. The structure of the deal is captured in a contract. Contractual service level agreements (SLAs) are the metrics that match client business objectives to quantifiable performance indicators. IT outsourcing SLAs often include commitments by the provider to perform some activity within an agreed to amount of time (e.g., resolve high severity IT-related problems in less than 60 minutes), or to maintain some minimal level of service availability (e.g., no more than 120 number of minutes down-time per unit month). Though SLAs are conventional and useful, achieving SLAs is just one measure of client satisfaction, and serve mainly as a starting point for a long-term relationship between provider and client (Blomberg, 2008). The client often has substantial responsibilities even after the contract is signed, for instance alerting the provider to problems, providing information when appropriate, and even maintaining machines that might be physically located at the client site (Pinhanez, 2008). As service system entities, IT service providers depend on people, technology, and organizations both internally and externally, and engage in formal business relationships with clients and partners.

Contact centers. Contact centers staff the phones for an enterprise, handling contacts from customers such as order-taking, complaint-handling, or problem-resolving (Maglio et al, 2006). Most view contact centers as cost centers to be controlled or reduced. From a service provider's perspective, the model is simple: stop incoming calls when possible; if the call must be taken, minimize time to resolve it; if the problem cannot be resolved by phone, dispatch service at the lowest cost. Stakeholders include the client that has outsourced customer contact; the service provider; call takers; individual accounts; schedulers; ecosystem of business partners; and quality managers. Each stakeholder has distinct goals. For instance, the client wants reliable service provided in a cost-effective and high-quality way, and the service provider wants to increase revenue, reduce cost, and maximize profit. Analysis of stakeholders, their pain points, and their measurements reveal the interrelatedness of the system components internally and externally. By taking an end-to-end view, focusing on transforming the system by introducing appropriate processes, metrics, technology, and tools to work in concert across stakeholders, transformation can be accomplished as a combination of process changes, organizational changes, technology changes, and tool changes (Cheng et al, 2007). For example, if one area of high cost is call volume routed from Level 1 (basic, inexpensive call takers) to Level 3 (highly skilled, expensive call takers), several corrective actions may be taken. The problems that flow to Level 3 can be better understood and Level 1 call takers can be trained in those problem areas. Better tools for employees and self-service for end users can also be introduced. In the end, coordinating people, technology, and information across the system is the only sensible approach for improving performance of complex contact centers.

Banking services. We can consider bank loan approval as a kind of service system entity that requires customers to interact with bank documents and personnel (Alter, 2008). Stakeholders include the applicant, loan officer, credit analysts, loan committee, risk managers, and more. Processes include filling out forms, sharing documents, approval processes, and explanation of results, among many others. More precisely, requests may arrive by phone (inquiries), mail (customer requests and communications with branches), and daily computer-generated reports identifying problematic accounts that require immediate action, such as overdrafts, and missing payments (Oliva & Sterman, 2001). For most requests, either a letter or a phone conversation with the customer results. The organizational incentives and lines of communication within the bank must be appropriately aligned or else performance will suffer (Oliva & Sterman, 2001).

Internal process transformation. Process transformation in any large enterprise can be difficult, as it requires transformation in social, technical, and organizational systems at once (Sanford, 2006). For instance, deploying a new technology to replace a web-based ordering system required alignment of stakeholders including the CIO's office, the team responsible for web ordering, the team developing the new technology, client organizations, and more (Krishna, Bailey & Lelescu, 2007). Different stakeholders have different incentives. A change that looks appropriate to one stakeholder (e.g., for cost reasons) might seem inappropriate to another (e.g., harder to use or integrate into existing systems).

Making Progress: Structures and Mechanisms Coevolving

Abstractly, service science studies entities, interactions, and outcomes. The entities are dynamic configurations of resources. When the entities interact to cocreate value, they access resources in a coordinated and purposeful manner. Consistent value cocreation outcomes are not accidents – they depend on sophisticated structures and mechanisms. More concretely, over the course of human history, the structures and mechanisms that give rise to value cocreation both change and remain the same. Division of labor (mechanism) within families or kin groups (structure) existed thousands of generations ago, and today division of labor within businesses and nations is still visible. Yet many modern value cocreation mechanisms (and their associated structures) also exist – such as compound interest (banks), installment payment plans (retail stores and credit card companies), and granting patents (nations).

In this section, we connect service-oriented structures and mechanisms to reasoning with symbols about the knowledge of value (and value of knowledge). To achieve this connection, we revisit the concept of *physical symbol systems*, and show that service systems are in fact physical symbol systems.

Physical Symbol Systems

Simon (1996) suggested that sciences of the human-made ("artificial") world ought to complement sciences of the natural world. The human-made world contains two primary types of artifacts: physical artifacts such as a car, and symbolic artifacts such as the Pythagorean Theorem. Both are outcomes of human creativity, one tangible, the other intangible. Further thought reveals two secondary types of artifacts: organizational entities such as the United States, and professional entities such as jazz musicians. Of course, it is no accident that these four types of artifacts correspond to the four types of resources in service science (Spohrer & Maglio, 2010): A car or any other technology or part of the environment is physical and has no legal rights; the Pythagorean Theorem or any other shared information is not physical and has no rights; the United States or any other formal organization is not physical and has legal rights; a jazz musician, a person, is physical and has rights. We view service science as one of Simon's *sciences of the artificial*.

Simon (1996) observed that the growing hierarchical complexity of the artificial world was not unlike that found in the biological world. Hierarchical complexity means that common building blocks can be found repeatedly, thus demonstrating that complex things are built from simpler things, if one can just understand the mechanisms that prefer certain combinations over others. For biology, Darwin's (1872) theory of evolution proposed the mechanism of natural selection to explain the way that essentially random processes could give rise to the diversity and complexity of species. Kaufman (1995) proposed autocatalysis as an additional mechanism to explain the chemical foundations of certain biological processes in networks that underlie the complexity and diversity of biological species. Mechanisms are part of the explanations for how complex structures arise – *mechanisms and structures coevolve*.

Simon (1996) saw a profound and essential difference between the two types of complex systems, natural and artificial. Unlike the biological world, artifacts in the human-made world are designed with a purpose: cars for transportation, Pythagorean Theorem to solve construction problems, the United States to form a more perfect union, and jazz musicians for entertainment. Human-made artifacts serve a purpose. Symbols and symbolic reasoning are used to make and improve artifacts. Humans are unique in the quantity and quality of symbol use, a truly symbolic species (Deacon, 1997).

Newell and Simon (1976) posited that physical symbol systems are necessary and sufficient for intelligent behavior of systems in the real world. Symbols can be generated in an arbitrary way (interpretation), put into correspondence with items in the world (designation), and support accumulation of new knowledge (learning). Broadly speaking, a physical symbol system is a real-world entity that uses symbols to shape its future behavior. The symbols must be encoded in physical substances. The symbols must be used to guide both internal behavior and mediate interactions with the environment.

Service systems are physical symbol systems that compute the changing value of knowledge in the global service system ecology. Structures and mechanisms are coevolving based on knowledge of how best to use symbols to calculate value. This does not mean that symbols are the only way to calculate value; we suggest only that the concept of value includes symbolic reasoning (along with much more). Nevertheless, structures and mechanisms are coevolving in a highly constrained manner because of increasing use of symbolic reasoning in processes of valuing, that is, in the algorithms people use to calculate value. For example, if our algorithm for calculating value is "benefits minus costs," then the coevolution of structures and mechanisms for value is shaped by "benefits minus costs." Of course, the constraints also include real world selection pressures and autocatalytic properties of value cocreation phenomena. If our algorithm for calculating value is flawed, reality will eventually show through. So if mortgaged-backed securities in fact are not spreading and reducing risks, but instead are concentrating and increasing risk in a few institutions, then the bubble will burst and our understanding of the value of that knowledge will begin to be adjusted. The bottom line is simply to understand that structures and mechanisms are coevolving, and service science should help explain both history (how did we get here?) and possible futures (where are we going?).

History: How did we get here?

The coevolution of structures and mechanisms is part of every science, and begins with physics (particles and forces) and proceeds forward. Chemistry (molecules and forces) and biology (life forms and processes) arise next in the sequence. One view of biology is in terms of three levels of structures (uni-cell, multi-cell, and neural-social).

Service science can also be viewed in terms of three levels of entity structures (informal, formal, and globally-integrated-formal). Because structures and mechanisms coevolve, informal entities begin when spoken language (cognitive technology) and tools (physical technology) in family or kinship group structures support division of labor and coordinated interactions at a level that separates humans from their primate ancestors (Deacon, 1997). Formal service system entities begin when written laws, money, and agriculture in early towns and cities support division of labor and coordinated interactions that separates urban dwellers (and those connected into extensive supply chains) from hunter-gathers living directly off the land (Seabright, 2005). Trusting strangers and mechanisms for validating identity and reputations of entities becomes increasingly important, when one is in frequent contact with strangers in roles, rather than well-known kin in roles. Next, globally integrated formal service system entities begin when the internet and smart phones in early on-line communities and social networking structures allow division of labor and coordinated interactions to expand into blended virtual and augmented-reality worlds for IT-augmented humans and enterprises (Engelbart, 1962, 1980; Spohrer, 1999; Spohrer & Engelbart, 2004; Palmisano, 2006).

Friedman (2008) provided a recent evolutionary account of humans changing to address the fundamental social dilemma: what is good for the individual is not always what is good for the group. Morals are a group's shared understanding of what is right and wrong, and how people are supposed to behave, especially when opportunities for cooperation present themselves. What biologists call mutualism, economists call mutual benefit – and its existence is not easy to explain.

Only within the last fifty years did *kinship selection* (the so called "selfish gene") arise as an explanation. Simply put, the more closely related two people are, the more logical it is to suppose that what benefits a kin in fact benefits the individual. So if people behave according to a "kinship enhanced" value equation, genes are more likely to accrue benefits and survive, even if an individual sacrifices some benefits or incurs some additional costs. Assume that an individual is likely to perform an action if the likely benefits (B) minus the likely costs (C) are greater than zero (B-C>0). The kinship-enhanced value equation that promotes the survival of the family genes is simply (rB-C>0), where r is the degree of relatedness of the individuals. For an individual or an identical twin, r=1.0. For an immediate family member (mother, father, sibling), r = 0.5 because half the genes are in common. Uncles and aunts share a quarter of their genes with nieces and nephews, so r=0.25. The survival of the family genes is improved with this kinship-enhanced value equation.

But what about cooperating with those who are not related? That is, when the one who benefits (recipient) does not have a significant number of genes in common with the individual who incurs the cost of helping. Only within the last forty years has an explanation arisen that piggy-backs on top of the kinship-enhanced value equation. The mechanism is known as *reciprocity*, and involves the social norm that maintains one's reputation as a useful identity in a group. Reciprocity says that it is important to reciprocate and return gifts of roughly the same value or slightly more value after a not-too-long period. The "reciprocity enhanced" value equation is simply (dB-C>0), where d plays a role similar to r and can vary between 0 and 1. Specifically, d=q/(1+i)t, where q is the probability the favor will be returned (0 to 1) based on the reputation of the individual, i is an applicable interest rate (for weighing alternative investments of time, effort, etc.), and t is the time delay (0 to infinity). Assuming that recipient has a good reputation as a reciprocator, and the cost is relatively low, then whether the recipient helps, the genes are likely to have an increased chance of survival through cooperating with others. As in the evolutionary accounts of Wright (2000), Seabright (2005), and many others, Friedman's (2008) account highlights that mutual benefits and learning better ways to play win-win, benefit-benefit, or non-zero-sum games – what we call value cocreation – is central.

Future: Where are we going?

Locally, structures and mechanisms coevolve to improve repeatable value-cocreation outcomes. Whole segments of the economy change based on new knowledge that has an impact on entities' value equations and processes of valuing. For example, energy from wood, then coal, then oil or natural gas is a progression that has been influenced by reasoning about the value of new extraction and distribution knowledge.

So where are we going? How are the processes of valuing being changed by new knowledge about service systems operating in the areas of healthcare, insurance, education, government, and others? Or based on new knowledge in academic disciplines, such as engineering, economics, operations research, mechanism design, management of information systems, industrial and systems engineering, economics and law, and many others? How is new knowledge about failures changing things? As incentives in certain areas become more and more high powered to accelerate change even more rapidly, what safeguards are being put in place to ensure that risks are appropriately bounded?

Two ends of the spectrum seem especially poised for change: (a) people and education, and (b) planet and investment. We will examine each in turn.

People and Education. People are the fundamental building blocks of service systems, and they need to become better prepared by education and lifelong-learning experiences to live with and contribute to STEM-driven accelerating change. Figure 1 shows the range of systems and disciplines that 21st century professionals in general, and service scientists in particular, will likely need to know about in their job roles (Spohrer, Golinelli, Piciocchi & Bassano, in preparation; Spohrer & Maglio, 2010). The list of systems includes the major types for which people are customers. The list of disciplines includes those associated with the major dimensions of service systems.

The average person born in the later years of the US baby boom held 10.8 jobs from age 18 to age 42 (BLS, 2008). For individuals in modern society, relatively frequent job-role changes seem to be the norm. Preparing students for this type of challenging job-change environment is not easy. The days in which an engineer could find a stable career in one manufacturing business are gone (Smerdon, 1996). Today, life-long learning is needed to prepare engineers for a series of customer engagements or service projects, either as part of a consulting firm or as a specialist for hire (UK Royal Society, 2009).

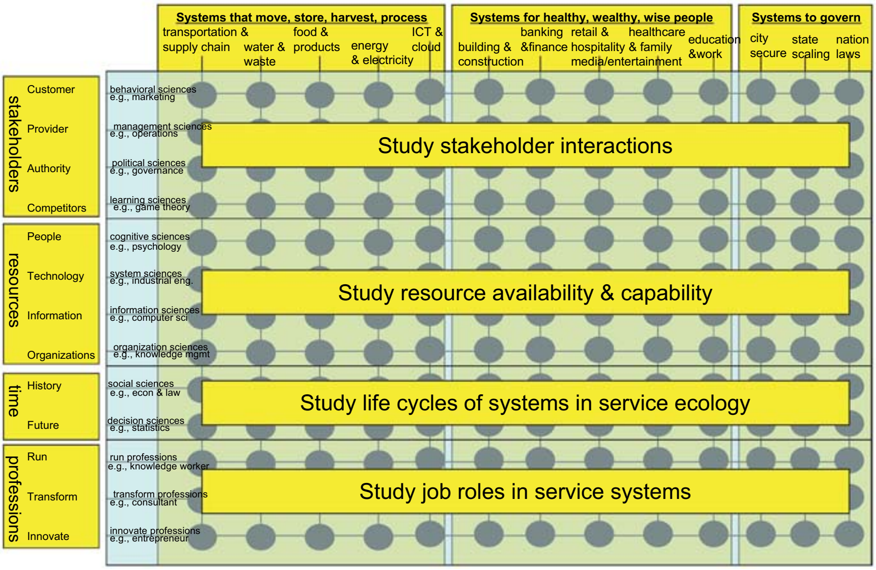

Figure 1. Service science: systems (13) and disciplines (10) or professions (3)

Figure 2 schematically shows what a T-shaped professional looks like with deep problem solving skills in one discipline and one system, as well as broad communication skills across many disciplines and systems (Donofrio, Sanchez & Spohrer, 2009; Donofrio & Spohrer, in preparation). The evidence that supports the need for more T-shaped professionals at the national level is beginning to appear. Using thirty years of economic data related to job descriptions, Levy and Murnane (2004) examined how computers create and enhance some jobs, while they eliminate and redistribute other jobs, resulting in a clear trend in U.S. occupational structure with most job growth in higher-end, high-skilled occupations, and most job elimination in the lower-end, low-skilled occupations. Their recommendation is to recognize this division and to prepare the population for the high-wage and high-skilled jobs that are rapidly growing in number – jobs that use computers and require extensive problem solving (depth) and interpersonal communication (breadth).

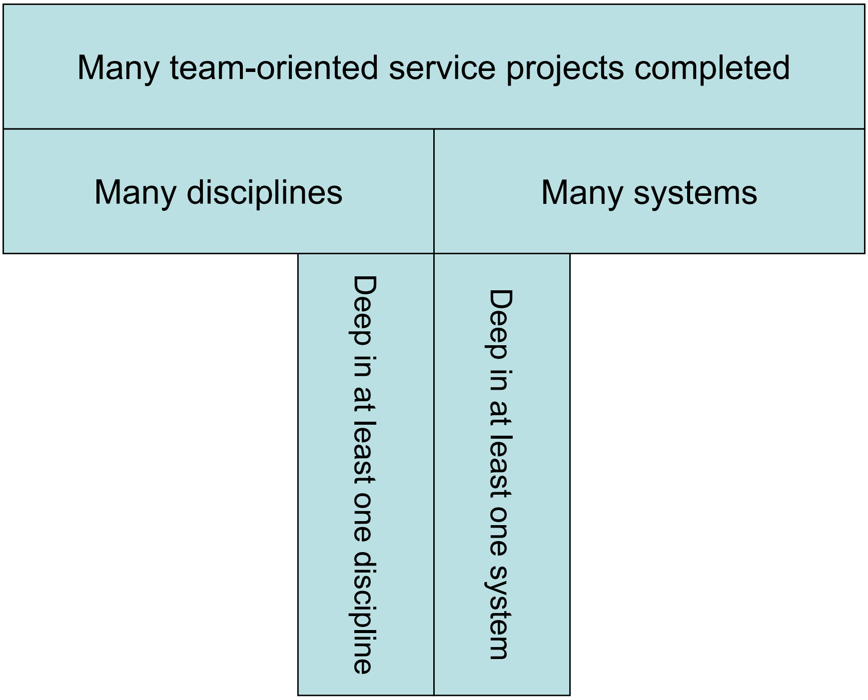

Figure 2. T-shaped professional: Deep and broad

Planet and Investment. Planet Earth needs an investment strategy that – like Moore's law for computing – leads to continuous and sustainable improvements in quality of life. Figure 3 depicts our world (largest circle) made up of many nations (next largest circles), states of regions (next smaller circles), and cities (next smaller circles) with universities (smallest circles) at their centers. In our view, each of these is a type of service system entity. The planet is getting smarter as more systems are becoming instrumented (sensors), interconnected (communications), and intelligent (algorithms help make decisions). For example, smarter cities will include many smarter subsystems, including transportation. Smarter transportation can be safer and more efficient in part because of more sensors in and around the roads as well as in cars and other vehicles that are wirelessly interconnected and can communicate about road hazards and congestions, as well as provide drivers with useful navigation and intelligent decision-making tools (IBM, 2009; see also Korsten & Sieder, 2010).

Each governing authority of each service system entity has a resource allocation decision to make – how many resources to allocate to run, transform, or innovate. As nations, states, and cities validate innovations, other nations, states, or cities that are ready can copy those best practices to improve their own operations. Becoming more systematic about these investments should lead to accelerating value cocreation, as more of the world's service systems benefit from applying proven knowledge to make their systems smarter. These efforts will be accelerated even further by the development of a computer-aided design (CAD) tool for service system design and engineering. Nearly all human-made systems that are on continuous improvement trajectories, from computers to buildings to cars, benefit from a CAD tool.

In sum, there are strong indications that improvements in coevolving structure and mechanism are poised for accelerating change (Singularity University, 2009; Spohrer & Engelbart, 2004).

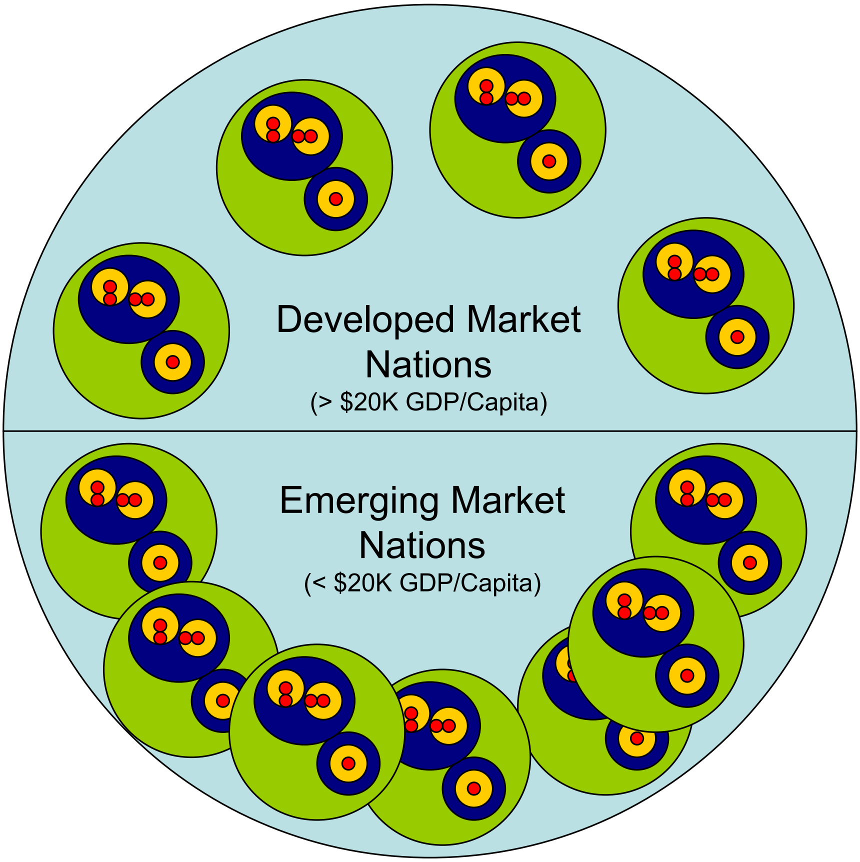

Figure 3. Planet Earth as a system of nested service systems

Conclusion

Natural sciences explain the origin and evolution of natural things. Artificial sciences explain artificial things – things designed by humans to serve a human purpose. Value cocreation is a human purpose. Service science is value cocreation science, and studies service system entity structures and their interaction mechanisms. Service science as a specialization of systems science attempts to integrate elements of many disciplines and systems around the theme of value cocreation (Spohrer & Maglio, 2010).

People accumulate knowledge of means (mechanisms) and ends (structural purposes). When means fail, we prop them back up or replace them with more reliable ones over time. People accumulate knowledge of means and ends that involve all the types of enduring resources that can be part of a service system entity: physical and non-physical resources, and resources with rights and without rights.

Change happens for a reason. Mechanisms underlie all events and all change. Scientists work to identify and validate symbolic representations of mechanisms. If change is predictable, it is because the mechanisms are well-established and stable. From a service science perspective, the social world (value cocreation mechanisms) arose from the physical world (physical mechanism) when people (the first service system entities) began to trust service (value cocreation) mechanisms (e.g., division of labor) the way they trust physical mechanisms (e.g., the sun will rise tomorrow). A sunrise does not require trust to operate, but division of labor does. Money stops working when we stop trusting in its value (Collins & Kusch, 1998; Friedman 2008).

Service science seeks to be a science based on reliable mechanisms, just as natural science is based on reliable mechanisms. From a human perspective, sometimes natural mechanisms fail to act reliably. This may be because assumptions are invalid, or other mechanisms are at work (e.g., a plane fails to fall from the sky because of Bernoulli's principle). The same is true of service (value cocreation) mechanisms. If assumptions are invalid or other mechanisms are at work, predictions may not be reliable. For example, when a computer program does not operate as predicted, it is because of invalid assumptions or other mechanisms at work. Science works to discover mechanisms, and to expose invalid assumptions and other mechanisms at work.

Here, we argued that service (value cocreation) and service systems are appropriate objects of study, and that a science of service can provide a foundation for creating lasting improvements to service systems. We sketched answers to a few basic questions about service, service system entity structure, and value cocreation mechanisms.

What is service? Service is value cocreation. Service phenomena occur when entities interact according to agreed to mechanisms that (normatively) result in value cocreation outcomes (win-win or benefit-benefit interactions).

What is a service system entity? A service system entity is a dynamic configuration of resources that can agree to grant access rights to its resources as a means (mechanism) to realize value cocreation ends (structural change outcomes) from its interactions with others. Types of service system entity structures include: people, businesses, not-for-profit organizations, universities, cities, states, nations, and non-government organizations. Our world is a diverse (multiple populations) ecology of interacting service systems. Service systems adapt to the changing knowledge of value (and value of knowledge) in the ecology. Service systems have run, transform, and innovate mechanisms to improve value cocreation interactions. They increasingly use symbols to represent, to reason and communicate about, and to implement value cocreation mechanisms. Symbolic reasoning is used to improve the reliability of the mechanisms, and recover more rapidly from failures.

What is a value cocreation mechanism? Mechanisms change the world (i.e., change structures, both physical and symbolic). Value cocreation mechanisms are either value-proposition-based or governance-mechanisms-based interactions that can create change. Value propositions are agreements between service system entities to share or exchange access to resources in order to change the world to their mutual benefit. Because all interactions are not value-proposition-based and not all value-proposition-based interactions do not realize value-cocreation according to plan, authorities can resolve disputes (using coercion, if necessary) to change the world in prescribed or novel ways.

What is service science? Service science is the study of service system entity structures and value cocreation mechanisms. Service science or Service Science, Management, Engineering, and Design (SSMED) aims to understand and catalog these structures and mechanisms. This understanding can be applied to advance our ability to design, improve, and scale service systems for practical business and societal purposes (quality, productivity, compliance, and sustainable innovation). Service science is a transdisciplinary undertaking and many academic disciplines have knowledge and methods to contribute, and practitioners working with real-world systems can contribute too.

In this chapter, we have set out the context and background, and pointed toward one possible direction for service science, namely a focus on symbolic approaches to understanding service system entity structures and value cocreation mechanisms. But nothing is settled. And much work remains to be done.

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