

Collaborative Innovation and Service Systems: Implications for Institutions and Disciplines

Nicholas Donofrio, Calline Sanchez, and Jim Spohrer, IBM
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Abstract: This paper explores the growing demand for collaborative innovation that is arising out of global growth opportunities. Collaborative innovation is changing institutions and academic disciplines in specific ways. Institutions are shifting towards open from closed. Disciplines are shifting towards integration from specialization. For example, holistic engineering and service science are both examples of *integrative disciplines*, as opposed to merely new specializations. In conclusions, we will show that institutions and disciplines can be viewed as part of a rapidly evolving ecology of service system entities.

1. Introduction: Growth and Collaborative Innovation

Historically, as new industries form at a national level, the three pillars of economic growth have been professions, infrastructure, and investment. More fully, these pillars are necessary skills and career development paths for new types of professionals (human capital), technological and institutional infrastructure (capital deepening and governance), and research and development (R&D) investment (innovation for efficiency and transformation). However, going beyond the boundaries of a single nation, new industry growth based on professions, infrastructure, and investment faces new challenges in light of global marketplace realities. With regard to IBM, no longer are we focused exclusively on the development, manufacturing and delivery of information technology, but rather on the application and integration of technology to deliver new and lasting value to our clients around the world. We have conducted an end-to-end transformation of our business, driven by major new global marketplace realities and opportunities. As a company with over \$100 billion in revenue, and which operates in nearly two hundred countries, we are aligned around a single, focused business model – collaborative innovation. Collaborative innovation is multi-disciplined, open, and global.

Collaborative innovation is the new imperative because of a fundamental market shift. All markets by their very nature exist to promote win-win interactions. The interactions are motivated by the premise that entities that interact will be better off after interacting than they were before; that is, interactions for both entities result in value creation, also known as *value-cocreation*. Historically markets promoted interactions that exchanged possessions to cocreate-value. In that old world, the three pillars of growth – professions, infrastructure, and investment -- performed quite well. Modern markets promote interactions that apply knowledge and competences (service) to transform the world and help people realize ambitions and aspirations. In this new world, the three pillars need revision. Open markets allow a wide range of entities (individuals, businesses, institutions, etc.) to interact and engage in collaborative innovation. Collaborative innovation is driving a new level of global, socio-economic transformation. We are in the midst of one of those rare inflection points that will forever change the way work is

conducted, the way new opportunity is created and how value is extracted from our endeavors.

As traditionally conceived of, the three pillars of growth – professions, infrastructure, and investment – work well for markets that are primarily directed towards product and production process innovation. However, for markets that are directed towards the innovation of business and societal systems and networks, the three pillars must be reconceived in the context of collaborative innovation. For example, professions require both deeper expert thinking and multi-disciplinary complex communication skills; infrastructure, both technological and institutional, becomes more open and adaptive; and investment, both short-term and long-term, is globally interconnected and interdependent. New opportunities and risks abound.

Nations and businesses that seek to overcome the challenges and thereby realize the new growth opportunities available through collaborative innovation are coming to understand a simple truth. Success does not depend on simply creating more scientists and engineers, but on creating new types of scientists and engineers. In the remainder of this paper, we first explore the trends associated with growing in new markets and the imperative of collaborative innovation. Next, we explore the nature of the new type of science (service science) and the new type of engineering (holistic engineering) that are needed to succeed.

2. Implications for Institutions: Nations and Businesses

2.1 The three drivers

We believe that the drivers of growth are different today and will remain so for the foreseeable future; they are propelling information technology and business services, and they are affecting not only IBM and the IT industry, but also the global economy as a whole. Further, a major factor in the accelerated growth of the American economy in the post-1995 period has been the increase in productivity gained by the application of information technology to business performance transformation services.

The economy today is moving into a new era, underpinned by cyber-infrastructure, a new architecture of computing as well as both the new business models and institutional infrastructures they enable. The essential ideas about the networked organization and global economy are clearly taking hold. Those changes are driven by the convergence of three historic developments:

Network Ubiquity: Global interconnectedness creates greater opportunities for collaboration. In roughly a decade, the Internet -- the most visible evidence of an increasingly networked world -- has reached over a billion people and is projected by some analyst to reach half the world's population by 2020. The Internet has not only connected people and opened up access to the world's information; it is rapidly becoming the planet's operational infrastructure. It is linking people, businesses and institutions, as well as billions -- ultimately trillions -- of devices. It is facilitating and transforming

transactions of all kinds - from commerce, government services, education and health care, to entertainment, conversation and public discourse.

Open Standards: Collaboration is required to establish open standards. Technical and transaction specifications underpin all industries. When they become standards -- that is, when they are widely adopted -- they enable growth by spurring the creation of many new kinds of products and services. Standards made possible electrical, telephone and TV networks, CDs, DVDs, credit and debit cards and global financial markets — and by extension, all the other business and public services those systems enabled. Today, standards are truly taking hold in information technology. They determine how computers operate and software applications are developed, how digital content is produced, processed, distributed and stored, and how transactions of all types are managed. These standards are “open” — that is, not owned or controlled by any one company or entity. (The Internet itself, for example, is built on open standards.) This is common in other industries, but a radical departure for the information technology industry.

New Business Designs: The simultaneous emergence of the networked world and open standards is enabling entirely new business designs, giving CEOs and other decision-makers options that were not feasible before. Companies can now be far more flexible and responsive to changes in the economy, buyer behavior, supply, distribution networks, consumer tastes, geopolitical realities — even the weather. That is because their business operations can be integrated horizontally, from the point of contact with customers through the extended supply chain. And because vital information is captured and managed enterprise-wide, networked companies can anticipate and respond much faster, or, in other words, on demand.

These fundamental shifts are creating significant competitive advantages for institutions around the world that master collaborative innovation, particularly in the management and integration of their business processes through networks. Companies are innovating in areas, such as supply chain management, engineering design services, human resource management, after-sales services and customer care. Governments are transforming their legacy agencies to organize around missions rather than departments. Academic institutions are delivering their courseware through the Internet in addition to the traditional classroom. Institutions are radically innovating in their business operations and processes using information technology and the services and expertise associated with business process transformation that embraces collaborative innovation.

Collaborative innovation is a worldview. The worldview we are espousing is based on entities interacting (people, businesses, institutions, nations, etc.), forming global networks, defining open standards to reduce transaction costs, and continuously benefiting from finding new business models to collaborate and improve each others' capabilities. Implementing the fundamental driver concepts is affording new growth opportunities in both economic and societal activity. Seizing the opportunities demands unique foresight and capability. As collaborative innovation takes hold, the availability of professional talent, infrastructure, and investment are increasing everywhere, making

the world more tightly integrated and dependent on collaborative innovation to survive and thrive. For companies, governments and educational institutions, the choice is either innovation or commoditization.

2.2 The changing nature of innovation

Perhaps the most important innovation occurring today is in the changing nature of innovation, itself. It happens much faster today and it diffuses more rapidly into our everyday lives; it is far more open; it spans virtually all disciplines and professions; it is increasingly global. Innovation almost never arises in the isolated laboratory anymore. It arises in the marketplace, the workplace, the community, the classroom. Innovation is a two-way interplay of creation and its uses, supply and demand, also known as value-cocreation. Understanding the changing nature of innovation is the first step toward marshalling our energies and resources to prosper in this new environment.

In 2004 IBM embarked on a first-of-its kind initiative to explore the changing nature of innovation and what it means for business, academia and society. IBM brought together hundreds of ecosystem partners from multiple disciplines around the world to focus on crucial societal issues that cut across businesses, industries, borders and cultures. Again, they included issues such as health care, work-life balance, and effective government. The initiative was called the Global Innovation Outlook. Among its key findings:

- Because innovation requires continual collaboration, workers in the 21st century no longer can rely on the expertise they learned early in life to keep them at the forefront of the skills queue.
- Colleges and universities are struggling to keep abreast of the fast-changing dynamic nature of work.
- Aspiring knowledge workers will need cross-disciplinary programs and degrees in order to compete. Historically, universities have found it difficult to provide such programs.

The Global Innovation Outlook also revealed that tighter collaboration among government, academia and industry is essential. It is the only way to spark innovation and drive solutions to the pressing problems we face. We heard this loud and clear, over and over, from government leaders, university presidents and senior business executives alike.

2.3 The innovation-commoditization cycle dilemma

Like other major structural shifts before it, the new era — globally networked, built on standards and with wholly new business and institutional models — is opening up new possibilities for profit and growth for business, while also affecting other realms of societal and economic activity -- from government, to health care, to education.

Seizing the opportunities presented by that shift, as always, requires unique foresight and capabilities. Despite the turmoil in the economy in recent years, some nations have managed to increase their prosperity, advance the frontiers of science and learning, and build multiple kinds of new expertise. For them, the result today is an economy poised for sustained growth in traditional markets and robust growth in the new markets.

Professional capabilities, infrastructure, and investment are increasing everywhere. Global interconnections make it possible for people to work from virtually anywhere. The world is indeed becoming more tightly integrated. For businesses in a broad range of industries – as well as governments – the choice is either innovation or commoditization.

Businesses that create new, high-demand technologies and services enjoy, for a time, barriers to entry, as well as superior margins and pricing power, since there are few other providers of that technology or service. However, alternative technologies or capabilities inevitably emerge, decreasing the innovator's advantages. In short, that segment of the industry "commoditizes." There are still attractive opportunities to be pursued, but with much less profit potential.

The global innovation-commoditization cycle has never been more pronounced than it is today, and it forces distinct choices. Winners can be the innovators — those with the capacity to invest, manage and leverage the creation of intellectual capital — or the commodity players, who differentiate through low price, economies of scale and efficient distribution of other parties' intellectual capital.

Perhaps the greatest risk is to get squeezed in the middle — being attacked by low-price competitors, while lacking the expertise and intellectual capital to keep up with the most aggressive innovators.

The innovation-commoditization cycle dilemma affects nations and businesses. Understanding, anticipating and managing the forces of innovation and commoditization can address many of the challenges to national economic success. Today, companies and organizations are coming to a new way of conceptualizing and managing the transformation and evolution of their systems and networks. Essentially, they are choosing to move to a higher value space in the overall national economic picture. A networked, interconnected model enables them to achieve higher levels of responsiveness, flexibility and efficiency than legacy, Industrial-Age business models. This new flexibility offers great potential for growth, by increasing productivity and by creating entirely new capabilities.

There are many examples of new capabilities. In health care, for instance, we now see personalized medicine on the horizon — as the integration of patient histories and genomic data is changing the nature of diagnosis and patient care. In insurance, we see products and services tailored to the driving habits of individual policyholders.

Collaborative innovation has become the new arbiter of national competitiveness. We must recognize collaborative innovation as a national priority. For the United States or

any nation to thrive in the hyper-competitive world economy they must, with urgency, mobilize business, government, educators and researchers to adopt collaborative innovation as a core strategy to build the foundation for a 21st Century knowledge- based economy.

Collaborative innovation success will be a product of many stakeholders collaborating and sharing the risk of change. To facilitate the process, national policy architectures must be modernized to address the changing nature of innovation and growth. The redesign of national innovation policies must be balanced, consistent and coordinated, and focused on crucial challenges.

2.4 Professions in a knowledge-intensive service economy

Professions relate to skills (education, training and workforce development) and career paths (job roles, advancement opportunities). Competitive advantage today comes from expertise – and expertise is not static. The collaborative innovation challenge requires maintaining deep and diverse collection of business and technology innovators, supported by advanced collaboration systems and a culture that enables continuous learning. In the Agricultural Age, land and farm production defined competitive advantage. In the Industrial Age, it was raw materials and manufacturing capability. Today, it is the ability to create and apply intellectual capital based on multidisciplinary expertise.

Workforce skills must include both technology and business expertise. An understanding of technology — its current capabilities as well as its future potential — is now integral to business decision making. Business leaders need innovation partners who are at the frontiers of research and deeply steeped in the issues and dynamics of specific industries.

To advance business expertise, the nation's structural transition to a knowledge-intensive service economy needs to be supported by a deepened understanding of how service systems and networks support and interact with manufacturing and other more traditional activities. In fact, in today's global economy, the service sector provides the bulk of employment in high-wage economies.

A wide community is beginning to discuss the technical and social effects of new developments in global connectivity, automation, technology integration and Web services and a new scientific discipline is being opened. Leading universities are beginning to work with IBM to better understand the social and technical issues involved in collaborating across global enterprises. For example, the University of California at Berkeley has implemented a service science curriculum in conjunction with IBM Research -- much in the way the first Computer Science department was initiated at Columbia University. Federal research investment and collaboration could significantly accelerate learning in this area.

To advance technology expertise, we are convinced that education must be transformed and realigned to prepare students to become adaptive innovators. Reform must start with curriculum. Creative and integrative instruction can be achieved through the

development of integrated Problem-Based Learning (PBL) and Challenge-Based Learning (CBL) – both methodologies that are sure to enhance the development of much-needed skills – especially in the engineering and technical professions. PBL is specifically helpful in the development of scientific, mathematical and technical talent. It focuses on ill-structured problem solving, and provides deeper meaning, applicability and relevancy to classroom materials and the development of crucial analysis skills that are required in the workplace. CBL engages students in working on complex real world problems that have not been solved yet. An education system designed to support curriculum focused on acquiring discreet skills and memorizing information will not produce the leaders and innovators the world needs.

The information technology sector is experiencing a pronounced shift in demand for specialized skills that fuse industry-specific knowledge, information technology capability and business expertise. These skills enable the business performance transformation services described earlier. Organizations seek more integrated and customized technology and services solutions that create competitive advantage and enable innovation. New information technology jobs are mushrooming in areas like business analytics, security analysis, vendor management, service management, system integration, and others. IBM's clients seek business acumen, project management and leadership skills along with specific IT skills linked to open standards, networking and e-commerce. These emerging occupations require higher skills and they are well paid.

Finally, we must realize that we benefit greatly from a diversity of talent, a diversity of culture, a diversity of thought and insight from all over the world --- intra-national and international. Collaborative innovation does not happen in isolation. For most innovations, the days of the lone inventor are over. Collaborative innovation happens across the diverse communities required to sustain economic leadership in the 21st century. Every region needs immigration policies that enable it to attract and retain the diverse minds of the world. Regions with diverse populations can more easily connect globally.

In an expertise-based, global marketplace, the expansion of business into more diverse services is forcing us to re-think the types of skills and educational degrees that are needed to drive America forward. In fact, the whole services paradigm is enabling us to be more innovative in our approach to talent development.

Applied more broadly, our experience drives us to conclude that collaborative innovators need a culture of learning and skill building. Specifically, it means that technologists and business experts need to work closely together, not simply to share insights, but to create entirely new intellectual capital for competitive advantage – new types of value-cocreation mechanisms. We must build the capacity to apply new intellectual property to nurture and launch new high-value businesses.

Unlocking innovation also demands that we rethink our ideas about intellectual property (IP). Some believe the best way to provide incentives for innovation is by fiercely protecting the inventor's proprietary interest. Others argue that we should open the doors

and give full access to intellectual assets. An approach that offers a balance of those two extremes may be most beneficial.

While IP ownership is an essential driver of innovation, technological advances are often dependent on shared knowledge, standards, and collaborative innovation. The IP framework must enable both. We must protect truly new, novel and useful inventions. And we need to recognize that open standards can accelerate the interoperability and expansion of the global infrastructure. Because collaborative innovation is relatively new, the structure and processes to accommodate ownership, openness and access are evolving, and new creative models are emerging.

Economies around the world are replicating the characteristics that have given Western nations such an innovation advantage – highly-trained professionals, technological and institutional infrastructures, R&D investments, and highly-trained professionals – operating with an open market system. Many companies in rapidly developing nations such as China, India, Brazil and Russia are leapfrogging to new cyber-infrastructures and business designs. Emerging nations with limited legacy infrastructures are developing specific innovation strategies. They plan to drive economic growth by leapfrogging in infrastructure development, providing tax incentives that attract global investment, and seeking parity or even superiority in the value delivered by skilled professionals. These approaches are creating a highly competitive global economy.

2.5 Higher education in a knowledge-intensive service economy

Higher education is part of the institutional infrastructure of nations. Beyond the always-crucial role of producing graduates in the science, engineering, and professional disciplines, institutions of higher learning must collaborate with government and industry to transform how the pipeline of future skills is being built – skills that are needed in a global, knowledge-intensive service economy.

Many of the brightest frontiers of knowledge lie at the intersection of traditional disciplines. Advances in medical technologies, for example, integrate biology with physics, mathematics, materials sciences and software engineering. We have to find ways to break down traditional stovepipes and encourage collaborative and multi-disciplinary learning.

In addition to learning across scientific disciplines, we should encourage collaboration across technical, business and social sciences. Innovation requires individuals able to recognize how new knowledge could meet societal demands and translate potential into practice. That creates real and lasting value.

Universities and community colleges are key components of successful regional economies. Universities should embrace a culture of commercializing knowledge and be active partners in regional growth strategies with government and industry. Community colleges, too, should play a prominent role in an innovation economy. The NII recommends, for example, that we establish innovation management curricula for

entrepreneurs and small business managers. Community colleges have a history of adapting to the skill needs of their localities.

When it comes to growth through innovation, the debate usually centers on the post World War II formula for innovation – namely, more money for developing knowledge-intensive professions, especially in STEM (science, technology, engineering, and math education) areas, needed technical and institutional infrastructure, and R&D investment to create new knowledge. Today, we must set ourselves on the path to do far more.

We need creative and bold policies that recognize the need for a more systematic approach to research and teaching in service science and holistic engineering; that recognize the need for more multidisciplinary research; that recognize universities as the key component of regional innovation economies.

We have consistently found that open, standardized approaches to problems provide the fastest path to innovation and success. It is foolhardy, in this modern era, to have a cacophony of competing, non-complimentary approaches to managing records.

We also must recognize the need for structural change. Even if federal and state higher education resources were to increase dramatically, that, alone, would not achieve the objective of meeting the full career path needs of our citizens in a global, knowledge-intensive service economy..

Frankly, academia and government must be open to new ways of leveraging industry and private-sector resources to address our challenges. We are not tapping into this remarkable asset – global business acumen – to address issues such as teacher training, new measures of institutional performance and standards of learning, and reform in the accreditation process. Many of the most exciting PBL (Problem-Based Learning) and CBL (Challenge-Based Learning) projects will require even stronger collaborations.

The forces of global economic integration, and advances in technology, are presenting complex challenges that can be addressed only by embracing opportunities for change and future prosperity. The status quo cannot be an option.

Institutions of higher learning must open up and collaborate with industry and government to create a U.S. educational climate and culture that enables innovation to thrive. No institution can go at this alone. It must be a joint stewardship of industry, government and academia.

America has a long and proud history of recognizing when change is required, and then rising to the challenge. We are at such an inflection point today. As we work to transform our rhetoric into action, innovation must be our engine and urgency must be our fuel. Innovation – the process of innovation – the collaborative, multidisciplinary, open nature of innovation – will enable all of us to build a brighter future for generations of students and our nation.

2.6 R&D investment in a knowledge-intensive service economy

New knowledge is the fuel that invigorates professions and transforms national infrastructures, both technological and institutional. R&D investment increases the knowledge-intensity of the global service economy. Effective R&D investment is based on directional roadmaps, associated progress measures, as well as supportive and aligned policies.

Achieving collaborative innovation success is complex. It requires far more than the management of ideas, technology transfer and research and development. The challenge is not only to generate fresh ideas and intellectual property, but to transform ideas and intellectual property into new value in an open marketplace of continuously transforming entities. Commercially successful transformation services are highly prized in the new open marketplace. The private sector is the primary agent for innovation. The Federal government, however, has enormous influence over the pace of fundamental knowledge advances, the incentive for private enterprises to invest in innovation and the conditions under which innovation may thrive.

Collaborative innovation is not just R&D investment driven (a supply side thought). It needs to be viewed on both the supply and demand side, from a global, value-cocreation perspective. A basic prerequisite for the next generation of innovation policies is to move toward a thoughtful balance between internal supply development and external demand development. The push and pull of supply and demand do not occur in a vacuum. They are strongly influenced by public policy and the overall infrastructure for collaborative innovation offered by our society. Public policies related to education and training, research funding, regulation, fiscal and monetary tools, intellectual property and market access demonstrably affect our ability to generate supply and respond to demands.

The same can be said of infrastructure – be it transportation, energy, health care, information technology networks or communications. Taken together, the institutional policy and infrastructure environments create a national infrastructure platform that can accelerate – or impede – the pace and quality of collaborative innovation.

Many of the critical choices lie outside the traditional sphere of research and development investment and innovation supply policies. Policies which influence the supply of talent, risk capital, the demand for innovative goods and services and the robustness of regional innovation networks also are important. A higher level of national innovation performance will result from an integrated end-to-end (idea to market) approach by the federal government. The vitality of the ecosystem will stimulate innovation. Focusing only on the discrete components – investing in schools or sector-specific initiatives – is not enough. To stimulate collaborative innovation, we must find ways to address the entire ecosystem, including efforts aimed at the following four areas:

1. Creating new metrics for the national innovation ecosystem to drive performance and monitor results. New metrics of the knowledge-based economy should include knowledge indicators, such as those derived from contractual agreements like strategic

partnerships, IP licensing, and conditions for innovation, such as economic demand, public policy environment and infrastructure readiness. Implementing a legal and regulatory framework that encourages voluntary and more complete disclosure of business intellectual (“intangible”) assets and longer term innovation strategies. Such disclosures provide a basis for better metrics of the knowledge-based economy.

2. Implementing new tax incentives to provide scholarships for the next generation of scientists, engineers and innovators and changing immigration policies to attract and retain the brightest talent from around the world. Tax incentives can also help shift resources to the most impactful emerging areas of science and engineering.

3. Modifying the long-term Federal R&D investment portfolio by a new priority on emerging science and engineering areas, setting aside an increased proportion of research funding to basic, novel, high-risk and exploratory research, including establishing a research program for the service science and holistic engineering, encouraging multidisciplinary research, and making permanent a restructured R&D tax credit including university-industry collaborations. Capitalizing on innovation opportunities in emerging areas such as new energy and materials, nanotechnology, green technology, mobile and social, medical records and health care, modeling and simulation of complex business and social systems.

4. Coordinating and focusing federal economic development programs on regional innovation hotspots and creating more dynamic innovative industry clusters. Accelerating innovation oriented learning environments at the K-12 level, enhancing careers options and the adaptability of workers through portable learning benefits. Development of professional capabilities can be accelerated by innovative infrastructure, both technological and institutional.

The directional roadmap for R&D investment in a global, knowledge-intensive service economies is aimed at building collaborative innovation capacity throughout the ecosystem of entities that participate in the open marketplace.

2.7 Succeeding in collaborative innovation

CEOs, government officials, academic and community leaders around the world are all counting on “innovation” to be the fundamental driver of economic opportunity, job creation, business competitiveness and advances in education, health care and a vast range of other disciplines. Investing in innovation, they say, is the surest way to survive and thrive in today’s complex, connected world.

But what do they really mean when they talk about innovation? Inside the information technology industry, innovation has been defined historically by the process of invention and discovery, and driven by R&D investments. Bell Labs, Xerox PARC and IBM Research, along with basic research programs at the world’s leading universities, epitomized the innovation engines of the 20th century.

They also operated in classic “ivory tower” mode – highly secretive and proprietary in their approaches, sharing little with others and, as a result, sometimes suffering from painstakingly slow paths to market for their best ideas. But the world has changed dramatically over the past decade – and even more so the basic nature of innovation itself. This shift to collaborative innovation first became evident with the rise of the internet, open standards, and new business models that threatened incumbents..

One of the key themes that emerged from a 2006 CEO study we conducted was that external collaboration is indispensable for innovation. We interviewed nearly 800 CEOs, representing a wide swath of geographic areas, a range of annual revenues, and everything from small and medium businesses to large, global enterprises. When asked which sources their companies relied on for their innovative ideas, “business partners” were right near the top of the list, just behind the general employee population.

“Customers” rounded out the top of the list, meaning that the top three significant sources of innovative ideas are predicated on open, collaborative approaches, including reaching outside the organization. In fact, CEOs said they are getting about twice as many innovation insights from customers as they are from their own organizations.

Perhaps most surprising was that “Internal R&D” was second-to-last on the list. As a career engineer and scientist-turned businessman, I would argue that those who do not see value returning from their R&D investments are not managing their portfolios to reflect the changes underway in the marketplace. In other words, they still are not collaborating externally and working directly with their customers. IBM Research is in the midst of a renaissance as a result of embracing market input.

The CEOs also told us that partnering -- whether crossing internal or external boundaries -- is easy in principle, but very difficult in practice. This is not at all surprising. Working with different groups to achieve common objectives usually requires a change in the culture of most organizations, and cultural transformations may be the hardest of all. We are convinced that to truly embrace a culture of collaboration you must accept limitations in your ability to get things done without help.

This is particularly important for those companies, like IBM, who are addressing problems in business, government, health care, technology and science that are very sophisticated in nature and pushing the limits of what is possible. We have learned that we cannot work on problems such as information-based medicine, integrated supply chains or advanced engineering design unless we have established a very close relationship with clients, business partners, and even other vendors who might very well be competitors.

In such an environment, to boast about being "the best" would frankly be considered crass, a sign of corporate insecurity rather than the strength of a confident leader and partner in the value-cocreation game. Instead, you want to be known as a company that helps all the various members of the team succeed in whatever problems are being addressed. Rather than claiming that you are the most innovative of companies, you want

to be known as a company that helps those with whom you work become more innovative themselves.

The open movement makes all of that possible. It holds the potential to spark remarkable innovation—and also turn historical cost structures and investment models on their ears. The Linux operating system, for example, is owned by no one, yet owned by everyone at the same time.

Thousands upon thousands of programmers around the world contribute to it and make it better, creating a checks and balances system that would be impossible with proprietary, closed systems.

Historically, we know it takes about \$1 billion to bring an enterprise-ready operating system to the marketplace for one computing platform. By working with the open community, we at IBM were able to get Linux across our entire product line with about one-fifth the investment we would normally make for just one platform. We did it through a combination of Linux code developed by the community, Linux code we contributed to the open community and Linux code we developed uniquely to better support it on our products. As a result, our offerings are better tested, more robust and are market-ready more immediately.

The open movement creates a common base for infrastructure, so that the wheel never has to be re-invented. The basics are already there and agreed-upon by the global community. That enables creators to leapfrog over the mundane, and jump right to the innovative – being assured that the infrastructure is sound and secure because it has been refined and tempered by great thinkers around the world.

When more people have access to the building blocks of innovation, rich new perspectives and diverse influences are injected into the creative process. People begin to think in an interdependent, collaborative way -- across disciplines, and collaborating at the intersections between them.

True innovation, then, is driven by the ecosystem; by listening to and learning from the various constituents with whom you exchange dialog and who may add value to the discussion. By embracing your ecosystem, you tear down the boundaries of culture, geography and organization to rapidly generate ideas and act on changes.

The first step is modeling your organization's own ecosystem – all the major constituency groups that are vital to your business success. There really is no right or wrong model, unless you choose to go it alone.

Second, you need to commit to a two-way dialogue with each of these constituencies – and also foster interaction between them, both with you and without you. You cannot control them anymore, or simply pump one-way messages and demands out to them. They will go elsewhere and collaborate with more receptive partners.

Networks are not a new idea, of course. The business world has always comprised constellations of people working together to create value. But in the past, those relationships have generally been more limited and exclusionary in nature, bound by strictly defined legal agreements and financial understandings.

Over the past decade, however, the proliferation of communication networks has not only connected people, places and ideas in unprecedented ways, but also catalyzed the evolution of social structures. With the freedom to transcend physical and geographic borders more easily, we are more willing to partner within and outside our traditional boundaries of organizations and countries.

Because of that shift, the 20th-century business enterprise as we know it could be history. Increasingly, the motivating force that brings people together for work is less “a business organization” and more the collective enterprise – activities driven by a common set of interests, goals or values.

The trend is accelerating, and it will have profound implications on how companies think about everything from leadership to managing and motivating global talent. It will change the way companies approach innovation, itself. As boundaries dissolve, as more fluid relationships form, as ecosystems expand and as networks get larger, the very nature of decision-making for individuals, businesses and the world takes on a new shape. Local actions now have global consequences, and the reverse is true as well.

To pursue open, collaborative innovation, enterprises simply must find ways to tap into the potential of the skill, talent and creativity of people from different teams in different organizations across the globe. A company can only be as innovative as the collective capacity of the people who make up its ecosystem. And to attract and retain talented people, a company must enable those people to feel respected, as individuals, as professionals and as members of a team. The company must trust those people and encourage them to collaborate and innovate with colleagues within and outside the business, driven as much by pride of contribution as by loyalty to the company.

These new models for collaboration offer a financial payoff as well. Studies show that companies that outperform their peer groups are much more likely to have adopted business models that focus on core expertise and collaboration with partners, rather than by strengthening their command and control posture.

Consider Bharti Tele-Ventures, the largest private telephone company in India. It recently outsourced and integrated its core functions – such as network and program management, help desk support, disaster recovery, IT and billing – which freed it to focus exclusively on marketing and customer service strategies. As a result, Bharti tripled its subscriber base – from six to 18 million subscribers – in just 20 months.

But success stories like that do not come easy. As fewer companies directly control all aspects of their operations, it becomes harder to ensure that brand experience consistently lives up to brand promise. How can a company ensure that the individuals and business

partners who power its network fully understand its brand and are motivated to protect and uphold it?

During the Global Innovation Outlook sessions, several participants advanced a concept built around the term “Reputation Capital.” It describes a kind of currency for building trust in a prospective worker’s personal and professional qualifications. They cited examples such as Wikipedia and eBay, both of which built successful brands based on the contributions of hundreds of thousands of non-affiliated individuals.

In each case, there are standards in place enabling people to see and rate the integrity and credibility of contributors. The more a contributor consistently demonstrates a high level of accountability and quality, the more value the contributor garners. Even for businesses not built around the contributions of individuals, reputation capital has intriguing possibilities – especially for emerging global players who have only a virtual presence and no visible brand of their own.

We are convinced that the art of collaborative innovation will be the most distinguishing leadership characteristic of the 21st century. Universities need to teach it. Government policies and regulations need to facilitate it. Businesses need to practice it.

For collaborative innovation to become part of our collective DNA, we must accept the notion that the surest way to make progress and solve problems is to tap into the collective knowledge of the team. Networked enterprises are the future. No individual enterprise, no matter how large and talented, can afford to go it alone in today’s highly competitive, globally integrated marketplace.

Success in tapping into such a global marketplace of innovators and experts requires companies to first develop a sound understanding of the collaborative landscape and then decide on an approach that suits them the best. One size does not fit all in this regard.

Different models of networked innovation and offer a set of guidelines for companies to identify and prepare for the most promising collaborative innovation opportunities. As they emphasize, success also requires us to rethink the very nature of our relationships with innovation partners – what we need to control and what we need to let go.

3. Implications for Disciplines: Science and Engineering

3.1 Growing number of disciplines

In section 2, we focused on the realities that drive nations and businesses to make collaborative innovation a top priority. In section 3, we focus on what collaborative innovation means to science and engineering disciplines. Just as no nation or business is an island, no science or engineering discipline is an island. More specialization in the world creates both more disciplines and many more boundary zones that interconnect

disciplines. In fact, linear growth in the number of disciplines creates exponentially more possible boundary zones, or points for collaboration between disciplines.

Table 1 shows the growth of about one new engineering discipline per decade for the last two centuries. We indicate a specific year based on the formation of professional associations in the US (or internationally).

Year	Engineering Discipline	Association	Artifacts & Industries
Antiquity	Military	DoD	Cannons, tactics, supply chain
1852	Civil	ASCE	Roads, bridges, buildings
1880	Mechanical	ASME	Steam engines, machinery
1884	Electrical	AIEE/IEEE	Generators, grid, appliances
1907	Agricultural & Bio	ASAE/ASABE	Crops, orchards
1908	Chemical	AICE	Fertilizers, fuels, compounds
1948	Industrial & Systems	ASIE/IIIE	Factories, conveyors
1948	Computing Machinery	ACM	Computers, Info Tech (IT)
1954	Nuclear	ANS	Reactors
1955	Environmental	AAEE	Sustainable construction
1963	Aerospace	AIAA	Jets, rockets
1968	Biomedical	BMES	Medical instruments
1985	Genetic Technology	AGT	Bacteria, plants, animals
1992	Financial	IAFE	Derivatives, options
1993	Software	JCESEP	Applications, web sites
2007	Service Systems	SRII/SSMED	Healthcare, B2B ITConsulting
2008	Holistic	?	Healthcare, Transportation

Table 2 shows the conceptual relationship of these emerging disciplines to some fields of science and mathematics.

Year	Engineering Discipline	Science	Fields + Mathematics
Antiq.	Military	All	Ballistics, metallurgy
1852	Civil	Physics	Mechanics, materials
1880	Mechanical	Physics	Mechanics, materials
1884	Electrical	Physics	Electromagnetism (EM)
1907	Agricultural & Bio	Biology	Cellular mechanisms
1908	Chemical	Chemistry	Thermodynamics (TD)
1948	Industrial & Systems	All	Operations Research (OR), CSD
1948	Computing Machinery	Phys/Logic	EM, OR, CSD, Algorithms
1954	Nuclear	Physics	Nuclear
1955	Environmental	All	Complexity/System Dynamics (CSD)
1963	Aerospace	Physics	Fluid dynamics
1968	Biomedical	All	Sensors, EM, TD
1985	Genetic Technology	Bio/Chem	Genetics
1992	Financial	Economics	Algorithms, Econ, OR, CSD
1993	Software	Logic	Psych, Social, Econ, OR, CSD

2007	Service Systems	Economics	Psych, Social, Econ, OR, CSD
2008	Holistic	All	Psych, Social, Econ, OR, CSD

While these lists are not comprehensive (e.g., should expert systems engineering be in the list), it does provide some confirmation for the assertion that a major new engineering discipline is established about once a decade. We have no reason to believe this pace will slow down as we move into the future, and some reasons to believe it may actually accelerate. For example, robotic engineering, nanoscale engineering, virtual world/game engineering and design, organizational engineering and design, and crime scene investigation are just a few of the emerging areas. As global population grows, specialization and division of labor is likely to continue and intensify. However, wherever people (and their determination of value) play an important role in the dynamics of complex systems, as in industrial and system engineering, financial engineering, software engineering, service systems engineering, and holistic engineering, we can also see an integrative force, working against specialization alone.

3.2 Reasoning about the “shape” of professionals

The “shape” of a professional is a term we use to understand whether a professional is a deep specialist in one area (“I-shaped”), deep specialist in two areas (“H-shaped¹”), deep in just one area, but with good knowledge and communication skills across many other areas (“T-shaped), or not deep, but with good breadth, a generalist (“Dash-shaped”). Clearly, an even more intricate shape language could be created when one factors in distinctions such as rigorous theoretical knowledge (“book learning”) and practical professional experience (“real-world relevance”). For our purposes, most of the points we are concerned with can be discussed in the context of the four basic shapes above. However, it should be noted that given a set of science and engineering disciplines, the learning and work experiences of any particular scientist or engineer could be used to create a more complex shape language of professionals. Also, given the close conceptual relationships between certain areas of science and engineering, as well as overlaps in tools and methods, one might expect considerable variation in the amount of time it takes for a professional to attain certain shapes for particular sets of disciplines.

I-shaped professionals may be very good as a “lone” innovator, but not so good at collaboration, unless teamed with someone else who shares the same area of depth. Hence, they may have great difficulty with collaborative innovation, unless they work in teams with people of other shapes that overlap the I-shaped professional’s area of depth. Then the others on the team are able to communicate with and benefit from the I-shaped professional’s deep knowledge in solving new problems.

¹ H-shaped are also sometimes referred to as *Hybrid* professionals. Many applied computer scientists are H-shaped, deep in computer science as well as some application domain such as meteorology, physics, or another area in which they build simulations or application software to perform research. If a person is deep in two areas, and also has good breadth for complex communication across disciplines, they are referred to as Pi-shaped. A professional journalist is typically T-shaped, deep in communication theory as well as a versatile communicator in many topic areas. Professional science masters students tend to be T-shaped with depth in one area of science, as well as with broad communications skills across many business functions.

On the other hand, Dash-shaped professionals may be very good at collaboration, but not so good at innovation, since they lack deep knowledge that can allow them to solve new problems.

H-shaped professionals may be even better than I-shaped people at innovation, and even better at collaboration. The challenge of course is that it takes a great deal of time to gain depth, so depth in two areas typically takes a substantial investment of time.

T-shaped professional may be very good at collaboration, and good innovators, solving new problems in their area of depth as well. Like H-shaped people though, it takes a lot of time to master complex communication skills across a breadth of other disciplines.

In sum, H-shaped and T-shaped professionals may take twice as long to create as I-shaped and dash-shaped professionals, but in general we would expect H-shaped and T-shaped people to be much better at both innovation and collaboration – or being good collaborative innovators. Alternatively, in a population of life-long learners, we might find more H-shaped and T-shaped people at later stages in their careers, and more I-shaped and dash-shaped professionals early in their careers.

Levy and Murnane (2004) analyzed thirty years of occupational descriptions used by the US Department of Labor, and found evidence for a strong trend in which types of skills were mentioned in newer occupational descriptions. Occupational descriptions show a clear trend towards requirements for expert thinking (problem solving) and complex communication (collaboration skills). These findings are consistent with the growth of a knowledge-intensive service economy. Both more specialization (expert thinking) and more integration (complex communication) are consistent with collaborative innovation becoming an increasing priority of organizations, and then reflected in their descriptions of occupations.

Computational organization theory researchers (Cataldo, Carley, Argote 2001) have used simulation techniques to explore the productive capacity of organizations in which the ratio of specialist (I-shaped professionals) to generalist (dash-shaped professionals) was varied. These studies indicate that in times of low rate of environmental change (fixed demand), organization composed of all specialists could maximize productive output. However, in times of rapid environmental change (shifting demand), organizations with higher numbers of generalists could out-perform other organizations. Again, these experiments support the notion that in a world where collaborative innovation is an increasing priority, organizations will compete best that are able to complement their I-shaped professionals with more H-shaped, T-shaped, and dash-shaped professionals as the rate of environmental change increases.

3.3 Understanding terminology related to disciplinary relationships

The term “disciplinary” refers to a body of knowledge on a subject. People can have different levels of facility with the body of knowledge that circumscribes a discipline;

some are novice and some are expert. For example, some people may only understand a discipline well enough to talk about some aspects of it, while others may be able to apply the knowledge in appropriate contexts and use the knowledge to solve problems, and still other may be able to contribute to the growth of the body of knowledge to solve even a wider range of problems. Students may only be able to talk about the knowledge, while practitioners possess the knowledge and use it in value-cocreation activities, and researchers can add to the growing body of knowledge that is their discipline, and hence allow a wider range of problems to have a solution within the discipline.

In discussions about collaborative innovation, one often hears the terms multidisciplinary, interdisciplinary, cross-disciplinary, and transdisciplinary. Some people use these terms almost interchangeably, but they are in fact different. Along with the term disciplinary (perhaps more correctly termed “intradisciplinary”), these five terms can be used to describe knowledge, people, types of research or educational activities, and teams of people.

The distinctions are sometimes subtle between these five: (1) disciplinary or intradisciplinary, (2) interdisciplinary, (3) multidisciplinary, (4) transdisciplinary, and (5) cross-disciplinary. Perhaps the simplest way to understand the distinctions is to imagine a population of people who value knowledge for its ability to stimulate productive relationships with others and help solve problems together (later, when we discuss service science, we will see that this is a simplified version of the *service systems ecology microworld*). Imagine these people know about a set of problems, some of which can be solved, and some of which cannot be solved. Very frequently, new problems are discovered as well. Very rarely, problems go away or are solved once and for all, and never need to be solved again in practice. Of all the problems this knowledge-valuing people know of, two are especially thorny, (1) making sure that knowledge is passed down to the next generation in an efficient manner, and (2) expanding the overall body of knowledge to allow new, urgent problems to be solved. Of course, we recognize the first problem as the education (knowledge transfer) problem, and the second problem as the research (knowledge expansion) problem.

A disciplinary community or project is made up of people who use their disciplinary knowledge to primarily solve problems. In addition to solving problems (service provider and customer relationship), the knowledge is also used to teach other as they join the discipline (teacher and student relationship) as well to create new knowledge and identify new problems that practitioners need to solve (researcher and practitioner relationship) that fall within the discipline boundaries. Disciplinary teams deal primarily with the knowledge application problem.

A multidisciplinary community or project is made up of people from more than one discipline that come together as equal stakeholders to work on complex problems that cannot be solved by a single disciplinary community alone. If the complex problem can be broken down into a set of problems that each discipline can solve separately and then reintegrate to solve the whole, multidisciplinary teams can be very efficient at repeatedly solving versions of the challenge. A multidisciplinary person is a person with the

knowledge to be a member of more than one disciplinary community. Multidisciplinary teams must deal primarily with problem decomposition and solution recomposition problems in addition to the knowledge application problem.

An interdisciplinary community or project is made up of people from more than one discipline that come together as equal stakeholders to work on very complex problems that cannot be solved by disciplinary or multidisciplinary communities alone. Interdisciplinary teams accept that more than a decomposition into existing disciplines is needed, but that new knowledge is required that may lie outside any existing discipline. Interdisciplinary work may result in the formation of new disciplines, the merging of existing disciplines in light of new knowledge, or the disappearance of old disciplines, as new disciplines take their place. Typically, an interdisciplinary person is multidisciplinary in two or several disciplines, with excellent complex communication skills across even more disciplines. Interdisciplinary teams must address the knowledge expansion problem as well as the knowledge unification problem – typically this leads to more disciplines, but can occasionally result in fewer disciplines, as some merge or are subsumed.

A transdisciplinary community or project is an ideal state that is unlikely to be achieved, but makes a compelling inspirational goal for many people. In a transdisciplinary community all members of the community have the complete knowledge of all disciplines, so in some sense discipline boundaries are irrelevant. In a sense the common knowledge of a transdisciplinary community is the sum of all the distributed knowledge of a multidisciplinary community. Transdisciplinary teams may address the knowledge transfer problem by first solving the knowledge unification problem, so less needs to be taught. For example, a transdisciplinary team might advocate Esperanto, as a standard language that could be taught to all people, providing a common language to solve any communication problem. Of course, this could also be viewed as transforming a multidisciplinary community (of many languages) into a disciplinary community (one language). Transdisciplinary is the belief that one “super-discipline” can be used to solve all problems and erase all discipline boundaries. An aspiration towards the unity of all knowledge underlies the notion of transdisciplinarity.

Finally, a cross-disciplinary community or project is one that is addressing the knowledge transfer problem, or the education problem. For example, when people in the music community want to learn physics, cross-disciplinary communities or projects may have created material that allows one discipline to be taught from the perspective of another. Cross-disciplinary teams address the knowledge transfer problem, not necessarily by unifying knowledge (to decrease the amount to teach), but by elaborating knowledge from more perspectives. Cross-disciplinary communities increase as the square (second power) of the number of disciplinary communities (e.g., discipline X taught from the perspective of discipline Y).

Armed with an understanding of the growth of disciplines, the shape of professionals in terms of discipline knowledge, and nature of the relationships between disciplines, we can now return to the challenges of collaborative innovation.

3.4 Service science

The service sector accounts for more than 75 percent of the US GDP (Gross Domestic Product). Given the total US population (about 309 million people, or 5% of the world's population), approximately half are employed and approximately 75% of those employed have jobs in the service sector. About half of the service sector jobs are knowledge-intensive (e.g., government, healthcare, education, business, and professional, etc) and the other service jobs provide numerous entry level as well as executive-management positions (e.g., retail, hospitality, and leisure). While service jobs are often thought of in pejorative terms, well more than half the service sector is knowledge-intensive segments and those segments are growing. Business and professional services, as well as healthcare services are the two fastest growing segments.

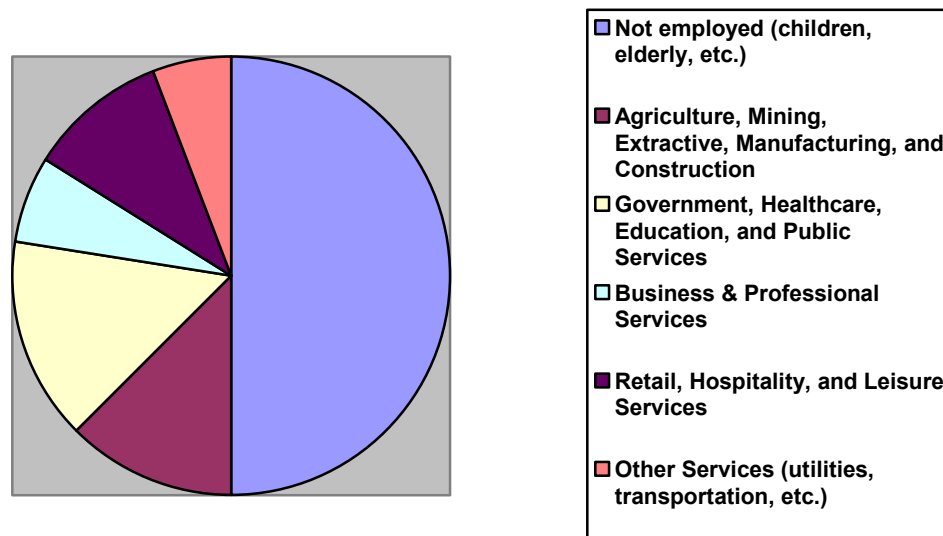


Table 3: US Population and Employment by Segments

The knowledge-intensity of many segments is growing as government, industry and universities invest to develop the workforce of the future. Even many sales jobs require a certain degree of technical skill in a knowledge-intensive service economy.

Service science² is emerging as a significant research discipline, initiated by IBM and university, industry, and government partners. SSMEED brings together ongoing work in

² Service science, an integrative science, is short for Service Science Management Engineering and Design (SSMED). From a business perspective, service science should explain how to invest (internal, external, and interface) in exploration and exploitation (March 1991). Investment is required to attain higher value-creation, value-capture, and opportunity-share future states. From a research perspective, service science can be conceived of as a science of the artificial. Simon (1996) in "The Sciences of the Artificial" provides a great deal of the conceptual foundations for what we now called service science. The outline of Simon's book provides an overview of the relevant topics: 1. Understanding the Natural and Artificial World, 2. Economic Rationality: Adaptive Artifice, 3. The Psychology of Thinking: Embedding Artifice in Nature, 4. Remembering and Learning: Memory as an Environment for Thought, 5. The Science of Design: Creating the Artificial, 6. Social Planning: Designing the Evolving Artifact, 6. Alternative Views of

computer science, operations research, industrial engineering, business strategy, management sciences, social and cognitive sciences, and legal sciences to develop the skills required in the knowledge-intensive service economy of the 21st century. SSMED students and faculty explore the current and future processes of business, as well as its human, technological and strategic elements. The SSMED course focuses on the issues involved in aligning people and technology effectively, to generate new value for both service providers and service clients.

The development of new skills -- and combinations of skills that integrated technical and business disciplines -- must begin at the university level, along with methods to scale the application of those skills. Over the past twenty years, academic centers have slowly increased the advancement of practical and theoretical knowledge of service businesses. SSMED encourages an interdisciplinary focus on service, as well as a more systematic approach to research and teaching the body of knowledge associated with service (i.e., service systems and service interactions). We believe these efforts will play a vital role in helping universities both improve the relevance of existing disciplines to the service sector and to overcome some academic disciplinary boundaries that were created in a bygone era.

The theoretical foundations of service science are based on ten concepts (Spohrer and Kwan 2009):

(1) Resources: Every named thing is a resource. Four types of resources are: physical-with-rights (people), physical-with-no-rights (technology, etc.), not-physical-with-rights (businesses, nations, universities, etc.), non-physical-with-no-rights (information). All physical resources have a lifecycle that includes a beginning, middle, and end. All not-physical resources exist as patterns in the possible physical states of physical resources, and are subject to coding errors (imperfect patterns).

Complexity, 7. The Architecture of Complexity: Hierarchic Systems). Over two hundred universities in fifty nations have begun SSMED-related education programs (Hefley and Murphy 2008, and personal communications update). These programs use a great variety of reference books, some undergraduate programs start with the accessible book by Teboul (2006), masters programs have started to use Ricketts (2007), and doctorate programs used the well established and top-selling Fitzsimmons and Fitzsimmons (2007), complemented by many other textbooks, books, and readings (see Spohrer and Kwan (2009) for an annotated reference list, which has been placed on-line - <http://www.cob.sjsu.edu/ssme/refmenu.asp>). Those seeking to formalize service science have benefited from "Reasoning about Knowledge" (Fagin, Halpern, Moses, Vardi 2003). Economist approaching service science for the first time have benefited from "The Economics of Knowledge" (Foray 2006). Business practitioners approaching service science for the first time benefit from a focus on value propositions provided in "Value Merchants" (Anderson, Kumar, Narus 2007). SSMED books have begun to appear (Springer Series: Service Science: Research and Innovations in the Service Economy, Eds. B. Hefley and W. Murphy), and there are increasing activities, including a nascent professional organization (www.thesrii.org - Service Research and Innovation Initiative), integrations into an established annual conference (Frontiers in Service), as well as integration into an established top-rated journal (Journal of Service Research). A growing number of existing academic and professional organizations have established SERVSIG groups (e.g., AMA, INFORMS, etc.). A service scientist is a T-shaped professional, with deep, expert, contributory expertise in at least one of these areas, and broad, complex communications, and articulatory expertise across them all (Collins and Kusch 1999; Levy and Murnane 2004). Finally, nations are creating service innovation roadmaps to establish investment priorities (IfM and IBM, 2008).

(2) Access rights: Four types of access rights are: owned-outright, leased-contracted, shared-access, and privileged access.

(3) Service system entities: Dynamic configurations of resources, people, organizations, shared information, and technology (Spohrer, Maglio, Bailey, Gruhl 2007). At least one of the resources has access rights, directly or indirectly, to all the other resources in the configuration. Normatively³, service system entities interact with other service system entities to cocreate-value. However, this is not always the intention or outcome of real service system entity interactions, which can be more like the outcomes of any two player game: win-win, lose-lose, win-lose, and lose-win.

(4) Value-propositions-based interactions (value-cocreation mechanisms): Normatively, service system entities interact to maximize short-term and long-term value-cocreation. They do so by communicating and/or agreeing to value-propositions with other service system entities.

(5) Stakeholder perspectives: All service systems can view themselves and be viewed by others from multiple stakeholder perspective. Types of stakeholders include the four main types: customer, provider, authority, and competitor. A good value proposition from a provider's perspective is one that is: in-demand (customers need or want it, and do not prefer self service), unique (only the providers can perform it), legal (no disputes with authority), superior (no competitor can propose anything better).

(6) Service system network: A set of service system entities that interact via specified types of value propositions during a specified time interval. Routine interactions are also known as business models. The simplest service system network is a customer and a provider connected by a value proposition relationship. A more complex service system network might include more actual customers, potential customers, employees, competitors, one or more authorities, and all the value propositions that connect these entities as well.

(7) Governance mechanisms (dispute-resolution mechanisms): A type of value proposition (often invoked by authority types of service system entities) when value is not created as mutually agreed, or when service system entities interact in non-normative ways.

(8) Measures: Four types of measures are: quality (customer as judge), productivity (provider as judge), compliance (authority as judge), and sustainable innovation (competitor as judge).

(9) Outcomes: From game theory, two player games have four types of outcomes: win-win, lose-lose, win-lose, and lose-win. Normatively, win-win is the desired outcome of service system interactions. However, service science proposes ten possible outcomes via the ISPAR (Interact-Service-Propose-Agree-Realize) model, based in part on the four

³ Normatively means when things behave as they ought to. Ought implies a value judgment by some entity.

stakeholder view: customer, provider, authority, and competitor (Spohrer, Vargo, Maglio, Caswell 2008).

(10) Service system ecology: The population of all types of service system entities that interact over time to evolve new types of the previous nine items; new types of (a) resources, (b) service system entities, (c) access rights, (d) value-cocreation mechanisms, (e) stakeholder perspectives, (6) service system networks, (7) governance mechanisms, (8) measures, and (9) outcomes. History is the trace of all outcomes over time.

3.5 Holistic engineering

Grasso and Martinelli (2007) state “In this evolving world, a new kind of engineer is needed, one who can think broadly across the disciplines and consider the human dimensions that are at the heart of every design challenge... Pursuing the holistic concept of the ‘unity of knowledge’ will yield a definition of engineering more fitting for the times ahead... Building quantitative-reasoning skills should still be a top priority for American engineering education, but that rigor should be complemented with developing students’ ability to think powerfully and critically in many other disciplines. To be sure, it will be a challenge, but a challenge with tremendous benefit.”

Grasso and Martinelli offer several examples of holistic engineering from the redesign of the Golden Gate Bridge to prevent suicides, to “cap and trade” permit programs to address acid rain, to “tax and drive” system to address traffic problems in major metropolitan areas. They note that “[IBM] has embarked on a research-and-business model that applies technological and manufacturing models to the holistic delivery of services.”

Holistic engineers are not simply problem solvers, but must also be problem definers and leaders of multidisciplinary teams. As the world creates more and more traditionally engineers, the risk of converting engineers into a commodity is quite real. The solution lies in the quality, and not simply the quantity of engineers. The 21st century challenge is both the additional time required to create better quality engineers as well as the establishment of higher value career paths for professional engineers. Service science may become exactly the type of integrative science on which holistic engineering can be firmly established.

3.6 Succeeding in collaborative innovation

Given the conceptual foundations of both service science and holistic engineering, we can create the notion of a *service system ecology microworld* that is intended to be recognizable as akin to, but a greatly simplified version of, the real world in which we all live. Imagine six types of service system entities: people, universities, businesses, nations, disciplines, and professions. Further imagine that each service system entity is given a generous initial set of technology resources that are owned-outright. People are given both shared-access and privileged-access to different sets of information resources that correspond to common knowledge and distributed knowledge in the society.

People have a primary allegiance to specific universities, businesses, nations, disciplines, and professions. Nations provide shared access to many technology and information resources. Shared access physical resources have capacity limits, so that when requests arrive they may already be engaged. We will assume that information resources have no capacity limit, so access to them can scaled tremendously at very little cost (e.g., the internet and world wide web). However, we will assume that knowledge resources (e.g., people) have capacity limits, so while access to them can be scaled, it comes at a much greater cost.

For the purposes of this paper, we will assert that T-shaped knowledge resources have at least two advantages over I-shaped knowledge resources, and one big disadvantage. The advantages are (1) lower communication and collaboration costs, and (2) lower learning and adaptation costs. The big disadvantage is that they cost twice as much to create in the first place, so that only if the nature of the world demands more communication, collaboration, learning, and adaptation can the initial investment cost be recouped. The world needs both I-shaped and T-shaped people, but getting the balance right is where simulations based on a service system ecology microworld may prove most useful. Of course, if everyone were to be made T-shaped, there would be a huge economy of scale targeting the creation of the broad part of the T. This could help significantly lower the cost of creating T-shaped professionals in a society.

4. Concluding Remarks

On any leader's agenda these days, few priorities are higher than collaborative innovation. It drives high-margin growth, strengthens competitiveness and creates jobs. It is no wonder that so many business and political leaders around the world have made collaborative innovation their number-one priority. From a service science perspective, people, businesses, nations, and other organizations, even disciplinary and professional organizations, are all examples of service system entities. Service system entities seek to interact (normatively – one might even say rationally) to create win-win interactions, and avoid lose-lose, win-lose, and lose-win. Only win-win interactions are good for both entities reputations and build trust, the catalyst of more win-win interactions (Normann 2001). Of course, in reality all interactions are not win-win, and thus there is a need for a deeper understanding of service system entity interactions (service science) and their design (holistic engineering). However, for collaborative innovation to work, we must stress these are not the same professionals, specialists and deep experts of the past. Service science and holistic engineering are integrative disciplines, and while professionals still must be deep in some area (traditional disciplines), they must also have complex communication skills across a wide range of other disciplines. Fundamentally, this is the change in human capital that is required to make collaborative innovation truly successful. The challenge is that educating T-shaped people may take twice as long and be twice as complex as training I-shaped people. Only this qualitatively different type of scientist and engineer can take us to the next level of growth through innovation.

For much of the past century, the United States was the world's innovation engine. Citizens of the United States, like those in key nations before us, can point with some measure of pride at both the technological and organizational innovations that have transformed the world in which we live. Today, more players are joining in this modern innovation game driven by rising skill levels of professionals, by open markets enabled by new technological and institutional infrastructure, and by significant R&D investments. Countries that until recently played a less visible role on the global innovation stage are emerging -- China, India, Brazil, Russia, Finland, Israel and South Korea, to name just a few. Collectively, those countries are producing five to eight times the number of science and engineering graduates than the United States. Moreover, 50 percent of America's science and engineering workforce is approaching retirement. Innovation is the arbiter of national competitiveness. Simply creating more scientist and engineers is not what the US needs. The US and all nations who want to excel at collaborative innovation need qualitative different types of scientists and engineers.

World-class scientists and engineers have always been fundamental elements of U.S. innovation, even before this era collaborative innovation. But let us not forget that the management of ideas, open markets, infrastructure and institutions, the enrichment of R&D capabilities and the development of new business models and process innovations are crucial, as well. In today's hyper-competitive global economy, science and engineering leadership, though very important, is not enough to achieve innovation. To strengthen collaborative innovation capabilities, it is not enough simply to intensify current stimuli, policies, management strategies and to make incremental improvements to organizational structures and curricula. For the 21st century, what matters most is what we find at the intersection of technology and human insight. Increasingly, the most important innovations will be those that transcend any particular business or technology; they will be those that have a broad societal impact and improve the lives of real people.

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