On the Co-Evolution of Information Technology and Information Systems Personnel

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Abstract

This essay addresses changes in information systems (IS) personnel and information technology over the past seven decades (1950s-2010s). A co-evolutionary perspective guides the discussion and emphasizes the mutual influence of changes in technology and IS personnel. The review considers (1) major eras of technical innovation and the steady expansion of the boundary that includes IS personnel; (2) the cyclical nature of a surge of needed technical skills with each technical innovation, a growing "shielding" of end users from the details of operationalizing the technology, and growth of end user domain application skills; and (3) implications for the education of IS personnel.

Keywords: Co-evolution, IS personnel, Historical analysis, IS globalization, IS workforce, IS education

ACM Categories: K.2, K.6.1, K.3.2, K.7.1

General Terms: Management

Introduction

Information systems (IS) personnel [1] represent a significant component of the sociotechnical systems that integrate computing, information, and work processes. To a large extent the history of IS personnel, per se, has been overshadowed by the dramatic and fascinating history of the technology itself. However, it is clear that no sociotechnical system centered around computing can exist without the workers who design, build, and manage application systems, who introduce them and other related IT into organizational environments, who operate, maintain, extend, and manage the IT, and who provide training, documentation, and support for the organizational context in which these systems are embedded.

Although there is much to learn from history, the lessons are not always simple and easily accessible (Land, 2010). It is particularly difficult to capture such

[1] In the early days professionals who worked with information technology (IT) were called "computer personnel". This terminology is still used periodically, but throughout this paper we will refer to people working with information technology as "information systems (IS) personnel" to include the entire continuum of workers who design, build, and manage application systems, who introduce them and other related IT into organizational environments, who operate, maintain, extend, and manage the IT, and who provide training, documentation, and support for the organizational context in which these systems are embedded. We use this terminology in reference to IS workers, IT professionals, and other phrases referring to those working with information systems.

lessons when (1) we remain close in time to the phenomena of interest, (2) the phenomena have many interconnected facets and can be assessed differently from the viewpoint of various stakeholders, and (3) the rate of change is extraordinarily high, as has occurred with the rapid co-evolution of technologies and IS personnel. Nevertheless, we believe that our experience as IS practitioners, teachers, and researchers provides us a viewpoint that helps us see informative patterns and underlying causes through a co-evolutionary lens applied to IS personnel and IT over several decades.

This essay makes the following contributions to the IS literature. First, it shows the influence of evolving information technology (IT) on the nature and range of IS jobs and skills. Second, it presents a co-evolutionary historical view that shows how the accomplishments and insights of IS personnel directly and indirectly lead to new applications and influence both overall demand for stronger and faster IT as well as help shape the direction in which such evolution of IT moves. Third, it identifies the pattern of change in required IS personnel skills following advances in technology beginning with demand for technical skills, moving to demand for skills in developing interfaces that shield users from direct interaction with the technology, then to skills for exploiting and innovating based on new IT capabilities. Finally, it suggests implications, particularly for university education and curriculum development resulting from the observation of these patterns.

We organize our observations and interpretation of history by starting with a review of the eras of IT that have characterized the technical landscape and an examination of the way in which roles of those working in the IS field or more broadly engaged with IT have changed over time. We then examine key issues related to knowledge, skills, and abilities (KSAs) in conjunction with changes in technology. We conclude with a discussion of the implications for education that derive from these observations and interpretations.

Before begining these observations, we briefly review co-evolution, the lens we use to interpret the history, since it has not been widely used in the information systems literature. We believe there is intrinsic value in understanding the co-evolution of IT and the people who create and use IT.

Co-Evolution Background

Co-evolution serves as a useful lens for considering the mutual influence of IS personnel as they have evolved with the accumulation of information technologies (IT) and their affordances. Consistent with our understanding and use of co-evolution, Vessey and Ward (2013, p. 286) provide the following definition:

> "Each element or component in an environment influences and is in turn influenced by all other related elements (components) in that environment in a process known as co-evolution. When a system changes to ensure best fit, its environment also changes, and those changes in its environment are likely to result in further system changes, and so on, resulting in continual system changes [reference omitted]. Adaptation by any system in an environment therefore alters both its own adaptation to that environment and the adaptation of all the other systems in the environment."

Other researchers have similarly used co-evolution as such a lens. Examples include Nelson (1995), who explains how industries and the policies and institutions that support them influence each other over time. Volberda and Lewin (Volberda & Lewin, 2003; Lewin & Volberda, 1999) propose co-evolution as a mechanism to simultaneously examine the effects of the business environment on firm extinction and the adaptation of firms that allows for on-going survival. Huygens, et al. (2001) use co-evolution to propose mutual causation of new business models in an industry environment and new structures for business operations in individual firms.

Examples from the IS literature include Luse and Mennecke (2014), who use a co-evolutionary perspective to justify why IT matters. Instead of adaptation or selection perspectives of organizational survival, they rely on a co-evolutionary perspective to explain how survival is dependent not just on selection or adaptation but on a combination of environmental selection and the adaptive capacity of organizations to make IT investments for competitive advantage. Vessey and Ward (2013) explain sustainable IS alignment through viewing information systems and organizations as complex adaptive systems that co-evolve over time. Benbya and McKelvey (2006) also view information systems as complex adaptive systems. They suggest an approach to information systems design (ISD) that views the process of ISD as ongoing and co-evolutionary. Their co-evolutionary approach (or framework) for ISD is based on "seven first principles of adaptive success drawn from foundational biological and social science theory: adaptive tension, requisite complexity, change rate, modular design, positive feedback, causal intricacy, and coordination rhythm" (Benbya & McKelvey, 2006, p. 12). Among the elements, or populations as a whole, that co-evolve are IS components, IS design experts, users and their initiatives, and internal, IS, and external environments.

It should be noted that scholars have not arrived at a single standard view of co-evolution. Winder, et al., (2005), for example, succinctly define co-evolution as "the evolution of two or more populations through the action of reciprocal selective pressures and adaptation between them." Direct co-evolution involves two populations of elements changing in response to each other, whereas diffuse co-evolution involves a more complex system of mutually influencing populations in an ecological system (e.g., see Lewin & Volberda, 1999). Thus, although some influences may be direct and obvious, others may be less so. Forces affecting changes may not affect all elements similarly or simultaneously. Causalities may be multidirectional and non-linear. Mutual influence has causal intricacy, as noted in the principles of adaptive success used by Benbya and McKelvey (2006); moreover, as Lewin and Volberda (1999) note, in complex systems of relationships, cause and effect become less meaningful.

Cortada (2007) extracts from causal intricacy both "supply-side" and "demand-side" influences in IT history:

Influence of IT (supply-side) on organizations:

> "IT drove out low-skilled work, increased demand for higher-order cognitive and technical skills, and allowed companies to lower their cost of doing business. For example, clerical work became increasingly automated in offices in many industries, while accounting was automated in all industries. Welding tasks in manufacturing increasingly became the purview of robotic devices. Programmers and systems analysts proliferated in all industries. Data entry clerks declined in number across the economy between the 1950s and the 1980s." (Cortada, 2007, p. 31)

Influence of users (demand-side) on IT:

> "[B]y looking at how computers were used by individual industries, one can begin to understand how technology and its uses were influenced by businesses. It turns out, the influence was quite substantial: banks causing the emergence and deployment of ATMs; the grocery industry aggressively forcing development of bar codes; retailers affecting the evolution of point-of-sale (POS) terminals and systems; manufacturers deploying CAD/CAM hardware, software, and new practices. The list is long and continues to grow. Research on the role of industries has confirmed the relatively unappreciated influence on IT of industry-level activities and institutions." (Cortada, 2007, p. 31)

The populations that are the main focus of this essay are IS professionals and IT. The components of the IS personnel population are individual IS personnel. As we will discuss, who is part of this population evolves over time. The evolving characteristics of IS personnel that affect our discussion here are their knowledge, skills, and abilities (KSAs) and their cost to employing organizations. The components of IT are software and hardware that could be used to support tasks in various domains, as proposed by their providers and determined by their users. Besides the tasks they support and their cost, the evolving characteristics of IT that affect our discussion here are the KSAs needed to adapt, implement, and use these technologies to support tasks. In addition to these populations we recognize that they are related to other populations in a broader ecological system. Among the other populations that we will discuss are organizations that employ IS personnel and acquire IT to support tasks, organizations that provide IT, individuals who use IT to support tasks, and organizations that educate IS personnel.

We have explicitly identified our definition of co-evolution, our two focal populations and their "genetic arrays" of evolving characteristics, related populations that contribute to diffuse co-evolution in our context, and the principle of causal intricacy that makes mutual influence much more diffuse than direct cause and effect relationships. In addition, we will frame our discussion using the following key ideas that we have abstracted from co-evolutionary works. First, strong forces (e.g., for adaptation and selection) can have mutual influence on one another. Second, patterns can be observed in a history of events related to these forces, e.g., evolutionary changes in the "genetic arrays" of populations can be observed. Third, underlying mechanisms shaping these patterns can be identified. As an example, the development (i.e., co-evolution) of specific KSAs of IS personnel (i.e., their "genetic array") in a specific IT environment is shaped by forces for generating value (from the co-evolving IT) for not only IS personnel but also their employers.

IT Eras and IS Personnel

Since the mid 1950s when computers first became available in the private sector, we have witnessed continual, and at times disruptive, change in information technology, its uses, and the professionals who enable it. As IT has evolved so, too, has there been an evolving understanding of who constitutes "IS personnel." Further, each new era of technological innovation has influenced and been influenced by a variety of strong forces that have also produced change in the IS field. Some forces are internal to the organizations that employ IS personnel and acquire IT to support tasks (e.g., pent up demand). Other forces involve not only these organizations but also those that provide IT as all these organizations pursue their goals (e.g., competitive pressures). Still others come from the broader ecological system (e.g., new laws and policies).

Although the influence on IS personnel of changes in IT may be more apparent than the opposite, we discuss in this essay ways in which IS personnel have, in turn, influenced the evolution of IT.

The history of information technology is often characterized in terms of “generations” or “eras.” Consistent with this approach we draw upon Hirschheim and Klein’s (2012) framework of four computing eras to facilitate our discussion of co-evolution. In this framework, one of the key levers of change from one era to the next is technological advancement (see Table 1). We add a new element to their framework: IS personnel, who co-evolve with IT through the eras. We make modest modifications to the time frames for their eras, which they note “tend to be fluid” (Hirschheim & Klein, 2012, p. 195). We also provide a descriptive label for each era to facilitate our discussion. Hence, alongside the technological evolution through these eras we add consideration of external forces and the evolving understanding of IS personnel.

Table 1. Eras and Technology (corresponding to Hirschheim & Klein, 2012, p. 196)

Era	Technology
First Era (mid 1960s to mid 1970s)	Third generation mainframe (IBM 360); Languages: Assembler, Fortran, COBOL; Database; Ethernet
Second Era (mid 1970s to mid 1980s)	Minicomputers; Mid-range computers; PCs; Fifth Generation Computer project
Third Era (mid 1980s to mid/late 1990s)	Internetworking leading to emergence of the Internet
Fourth Era (late 1990s to 2010s)	Internet Age; Ubiquitous computing (laptops, netbooks, tablets, smart-phones, etc.); Search Engines; Social Media

First Era: “Computing Inner Circle[2]“ (mid 1950s to mid 1970s)

The computer, a technology originally designed to solve complex mathematical problems for military applications during World War II, entered the private sector in the post-war 1950s and became embedded in large corporations in the 1960s. By the mid 1970s it was commonplace to find computers in large corporations. The hardware of this era was the large-scale mainframe computer; the processing was non-interactive batch processing. The proprietary software evolved from using first generation (machine) languages to second generation (assembly) languages to third generation languages which responded to the dual purposes of computing: scientific (e.g., Fortran) and business (e.g., COBOL). The quintessential business computer of this era was the IBM 360. With the broad-based extension of computers to business came a change in nomenclature. The term “business data processing” and, later, “management information systems” (MIS) emerged as the computer’s mathematical calculations were applied to finance, accounting and operations research problems as well. Toward the end of this era the term “information systems” (IS) came into use.

A broader ecological force running alongside the proliferation of computing technology in businesses was the economic expansion in post-war societies. Countries such as the United States experienced an economic boom brought on by steep industrial growth while countries in Europe and elsewhere were rebuilding their industrial infrastructures. This industrial growth was facilitated, in part, by the enhanced management decision making that automated data processing afforded.

But using the computer in these contexts typically required the specialized technical skills of IS personnel to extract useful results. These highly technical individuals served as a computing inner circle, gatekeepers of organizational information that emerged from these data processing machines. The output came in regular – typically monthly – intervals in standardized printouts. Exception reports were often more easily completed manually. A request for new information could take considerable time to answer (e.g., months or, even, years) as a unique computer program would need to be written along with other programs that could take precedence in a long queue of requests. The qualifications for IS personnel in this era initially included mathematics and engineering degrees until computer science degrees became available. Computing degrees with a business focus, such as management information systems, did not begin to emerge in educational organizations until late in this era.

The job titles of IS personnel in this era included MIS manager, systems analyst, programmer, and operator (see Table 2). Gibson and Nolan (1973, p. 24) noted that early in this era “one person typically designed a data-processing application, programmed it, and ran it on the computer. Rapid developments in hardware,

[2] In the early days of computing, only specialists were allowed to enter the room housing computers. Although this did not necessarily translate into power or control regarding the organization and its relationships in the marketplace, it did create an inner circle of those interacting with information technology.

mass storage, operating systems, and programming languages have forced a specialization of jobs and of personnel into the areas of application design (systems analyst), programming (application programming, systems programming, and now data base programming), and operations."

Table 2. "Computing Inner Circle" Era and IS Personnel Jobs

Era	IS Personnel Jobs
"Computing Inner Circle" Era (mid 1960s to mid 1970s)	Managers Systems Analysts with specialization in functional areas, e.g., finance, marketing, and manufacturing Programmers with specialization in application, systems, and database programming Operators (Based on Gibson & Nolan 1973)

Second Era: The End User Revolution (mid 1970s to early 1990s)

The mid 1970s ushered in the end user era with the introduction of minicomputers and fourth generation software. These were the first computer applications that enabled "lay people" to extract information from the computer. But whereas the late 1970s witnessed the nascent end-user era, the 1980s saw it come to fruition. Technological innovations that made information more accessible for management decision making were the new minicomputers which were operated by interactive computer terminals rather than punched cards, and database technology as well as data query capabilities of Fourth Generation Languages. But in the 1980s exponential growth in end-user computing accompanied the introduction of the microcomputer. Not only was there a new type of computer, a "personal" computer that each business person could own and use, there was also a revolutionary change in software. Until this time, software was tightly bundled to particular hardware. But along with the disruptive technology[3] of standard computer architecture found in "IBM compatible" personal computers, came "off the shelf" software that was no longer proprietary to a particular type of machine.

An organizational force that helped to fuel the spread of end-user computing was the pent up demand for better and timelier information to support management decision making. This, in turn, inspired hardware and software innovations that were pushing computing technology to become smaller, cheaper and easier to use. The influence of IS personnel on IT was indirect. The supply and cost of IS personnel and the KSAs required by IT to develop systems for individuals who used IT to support their tasks were contributors to the pent up demand within organizations and the impetus for providers of IT to respond with innovative IT that would address the pent-up demand.

The term "end user revolution" came to characterize this era of computing that was ushered in by these technological changes. Thanks to the new interactive capability afforded by computers and the accessibility provided by databases and new software tools, a broad array of users had, for the first time, direct access to computing resources. With small, cheap machines that ran off-the-shelf, user-driven software, even small businesses and people with limited knowledge about how computers work were now able to use them.

Along with this technological revolution, a fundamental change had occurred in our understanding of IS personnel. The inner circle of computing was opening up to a broad array of system users, thereby shifting the boundaries between computer professional and end user from being rigid and fixed to being fluid and permeable. In the previous era, the role of the computer professional could be broadly characterized as: 1) accessing the computer to get information for other people in the organization and 2) developing the programs that enabled computer professionals to extract this information. But with the introduction of the personal computer, a new era of software acquisition was ushered in. For the first time in the history of computing, people could purchase packaged software that they could use in their businesses. Further, the same software could work on more than one brand of personal computer. This resulted in fundamental changes in both of the roles previously held by IS personnel.

At the same time, influential work was occurring that had implications regarding those who are considered IS personnel. A landmark study conducted in the USA in 1977 sharpened our emerging understanding of a "post-industrial society" (Bell, 1973), or information society, even as it documented the broadening of the scope of IS personnel. As it did so, it introduced into the lexicon the term "information economy." In a 1977 report to the U.S. Department of Commerce, Porat (1977) characterized the information economy as that portion of the labor force engaged in the production of information and information tools.

[3] We use the term "disruptive technology" in a slightly broader sense than Christensen (2001) to indicate a sort of paradigmatic shift of predominant information technologies rather than a more specific change in a discrete technology. However, the idea of evolving technology resulting in an evolved competitive economic environment is consistent with his premises.

His analysis broke the information economy down into two information sectors. The primary information sector (or supply side, according to Cortada (2007)) is defined by the work of producing information and information tools. This sector includes those workers engaged in the production of information processing and communication hardware, software, information systems and services, and information content. The secondary information sector (or demand side, according to Cortada (2007)) includes workers engaged in information work in the context of some other industry. Whereas the output of the primary information sector is the information or information tools (such as computer software or communications technology), the output of the secondary information sector is a non-information good/service (such as health care, education, government); however, workers such as computer programmers in the secondary information sector are also IS personnel even though they are not in an IT company (Niederman & Trower, 1993; Trauth, 2000, p. 5). Nevertheless, the primary and secondary information sectors distinguished two different categories of IS personnel: those who worked at IT supplying companies (e.g., IBM) versus those who worked at IT demanding organizations (e.g., General Motors or UNESCO).

Understanding the distinction between primary and secondary information sectors but also recognizing that IS personnel work in both sectors is extremely important to understanding those included in IS personnel and the IS field. Trauth, et al. (2007) experienced the effects of this distinction in their action research project related to economic development in a region of Pennsylvania. They point out that the state had focused on economic development for industry clusters that would limit their efforts to develop IS personnel to those with jobs in the primary information sector. However, to count only IS jobs in the primary information sector would be to undercount the size of the IS workforce in most regions of a country. In the USA, for instance, with the exception of regions such as Silicon Valley, Research Triangle, North Carolina, Route 128 in eastern Massachussetts, and the Seattle-Redmond, Washington area, which Porat would characterize as the primary information sector, most workers who are considered to be IS personnel are employed in the secondary IT sector. Unfortunately, a reference to "IS personnel," the "IT profession" or "IT workforce," could be understood to include only those working in organizations whose output is information, knowledge, and communication goods and services. Such a limited understanding would not count the size of the workforce engaged in information, technology, systems, and knowledge work for internal use. Indeed, this perspective led Trauth, et al. (2007) to argue for a shift in thinking from IT industry clusters to IT occupational clusters.

Developments during this era changed our understanding of where we would find those who worked with information and computer technology. Increasingly, IS personnel moved out of the computing inner circle to become distributed throughout the organization. Some were information specialists reporting to other business functions, some worked in the centralized computing department of a demand-side organization, and others worked for both new and established supply-side computing companies, such as Microsoft and IBM.

This era, with IT that had evolved to be easier to acquire and use, also made it easier for more users of IT to become de facto IS personnel. However, even with the more permeable boundary separating IS personnel from users, most users did not become IS personnel. Most users shifted from accomplishing their tasks in a non-automated fashion to doing them using technologies built and maintained by others, remaining specialists in their task domain rather than transitioning to the domain of IS personnel. On the other hand, within the task domain some workers did shift over to being responsible for the design, construction and management of new application systems. Some of the work of these individuals enabled them to be viewed as IS personnel even if their line of reporting within the firm remained through their task domain area. Where an individual's primary activities are clearly related to both IS and non-IS task domains, the more that individual is a hybrid who would need KSAs in both the IS and non-IS task domains. The end user revolution made such hybrids necessary.

Besides helping distinguish IS personnel from users, the definition of IS personnel guiding our discussion also makes it possible to distinguish IS personnel from both computer engineers who design and build computers and computer scientists who design and build operating systems (rather than application systems). It also makes it possible to distinguish IS and non-IS personnel in supply- and demand-side organizations. For example, financial managers whose primary tasks are not clearly related to the IS task domain would not be IS personnel in either IT provider or user organizations.

The jobs of IS personnel in this era were more extensive and specialized than those in the first era. In a study of skills Lee, et al. (1995) used the classification of jobs extant at that time (see Table 3). Although these researchers did not break out managerial jobs from other jobs, it is obvious from their study that a managerial job classification is also an essential one for IS personnel.

Table 3. The End User Revolution Era and IS Personnel Jobs

Era	IS Personnel Jobs
The End User Revolution Era (mid 1970s to mid 1980s)	Managers Business Analysts/Systems Analysts, i.e., people responsible for planning, analysis, design and implementation of business applications Programmers, i.e., people doing software development, coding, software maintenance, etc. Computer Operators and Data Entry Clerks Technical Specialists, i.e., people with technical knowledge of specific hardware, operating systems, communication systems, database management systems, networks, etc. End-User Support Consultants, i.e., IS staff providing end-user computing support such as information centers, hotlines, help desk, and data retrieval (Based on Lee, Trauth, & Farwell 1995)

Third Era: E-Commerce Gold Rush (early 1990s to early 2000s)

Whereas the technological innovations of the end user era focused on computing hardware and software, those of succeeding eras revolved around telecommunications. By the early 1990s, the increased volume of both competition and innovation culminated in the introduction of the World Wide Web and commercialization of the Internet. The widespread accessibility to information technology applications that began with the personal computer and the ensuing wave of user-friendly computing was intensified with the introduction of the Web. What emerged from these technological and business innovations was the recognition of a new kind of infrastructure, a national information infrastructure, (Information Infrastructure Task Force, 1993) upon which a new type of business – electronic commerce – could be built. Consequently, the closing years of the 20th century became a virtual gold rush as entrepreneurs competed globally to develop the technology, applications and services to support this new type of commerce.

A range of forces laid the groundwork for the growth of this era. At a broad ecological system level, a wave of telecommunications deregulation and the accompanying emergence of competition that began in such countries as the USA, the UK and New Zealand in the early 1980s (Trauth & Pitt, 1992) spread to other countries throughout the remainder of the decade. By the early 1990s the Internet was a global phenomenon. By the mid-1990s electronic commerce applications that used the capabilities of the web were emerging. At the industry level, competitive pressures within an industry drove companies to establish a range of e-commerce capabilities including business-to-business and business-to-consumer applications.

The e-commerce gold rush era had implications not just for technological innovations and e-commerce entrepreneurs. It also redefined and relabeled the people who developed and used these systems. With the integration of computing and telecommunications, the older term “computer personnel” gave way to one that recognized this expanded technological scope. In practitioner circles, the term “information technology” largely came to characterize both the work and the workforce. During this era the boundary around those who could claim the moniker of “IS worker” was pushed out even further to encompass those responsible for the broader computer and communications infrastructure, sometimes referred to as information and communication technology (ICT).

In addition, a new community of IS personnel was emerging. It consisted of those focused on the development, deployment, and management of e-commerce applications. This new focus came from all areas of business including marketing, management, and logistics. Post-graduate degrees in electronic commerce proliferated. Particularly in the small start-ups, the individual who managed e-commerce applications might be the only “IS person” in the company. Gradually, the division between “brick and mortar” versus e-commerce businesses began to dissolve as more and more companies included an e-commerce component to their businesses.

The developments in this era illustrate and reinforce two patterns that become apparent as we look across eras. First, although our definition of IS personnel remains consistent across eras, the boundary that encompasses IS personnel continues to extend to encompass personnel in other task domains as they take on tasks in the IS domain as their primary tasks. Just as they did in the end user revolution era, when end users took on development and management of applications in their task domains as their primary tasks, boundaries expanded in the e-commerce era when marketing specialists took on development and management of e-commerce applications as their primary tasks. In addition, the tasks of communication specialists were redefined as belonging in the IS task domain. Second, as new IT emerges from provider organizations and organizations acquire that IT, such as database technology in the end user revolution era and e-commerce applications in this era, it becomes apparent that new kinds of IS personnel emerge, such as database managers and web developers.

Consider an alternative narrative to newly emerging IT leading to new IS personnel. For example, as organizations conceptualized technical solutions to address pent-up demand or to meet the gold rush opportunities envisioned with e-commerce, they built new capabilities in the form of IS personnel responsible for developing appropriate innovations. These IS personnel were instrumental in influencing IT vendors to expand technology capabilities, resulting in new IT. This alternative narrative has newly emerging IS personnel leading to new IT. The pattern of matching IS personnel and IT (e.g., IT requiring IS personnel who have database or e-commerce application KSAs), regardless of the sequence, is consistent with Benbya and McKelvey's (2006) principle of requisite complexity.

The jobs of IS personnel in this era continue the trend observed when moving from the first to the second era, i.e., they are more extensive and specialized. Based on a study of IS job skills listed in job ads published in 1988, 1995, and 2001, Gallivan, et al. (2004) reported skills for jobs that we have grouped as shown in Table 4.

Given the technical development of the internet during this era, the job of web developer did not appear in job ads in 1988 and 1995, but did in 2001. It is not obvious from the study how a software engineer differs from a programmer/analyst. The technical support jobs include user support. Based on material in the study, we infer that database administration jobs include database management and data architect. The sales/education jobs, although included here, are "non-IT positions in a software firm." Further, the nature of consulting jobs was not explained. The authors (Gallivan, et al., 2004, p. 81) did note, though, that "50% of ads originate from consulting firms seeking workers for temporary positions." Such positions illustrate that not all IS personnel jobs are permanent. They also illustrate the opportunities for jobs with IT providers that supplement the jobs of IS personnel in organizations that demand IT.

Table 4. Eras and IS Personnel Jobs

Era	IS Personnel Jobs
E-Commerce Gold Rush Era (mid 1980s to mid/late 1990s)	Management Project Leader Software/Applications Development Systems Analyst, Programmer/Analyst, Software Engineer, Web developer Technical Specialists and User Support System Admin, Network Design, Database Admin (database management, data architect), Technical Support Sales/Education (in IT vendor) Consulting* (Based on Gallivan, Truex, and Kvasny 2004)

* Based on the sources cited, consulting is not listed as a job in other eras; nevertheless, consulting services have existed across eras.

Fourth Era: Ubiquitious Computing (early 2000s to present)

As the new millennium dawned, the pace of technological innovation in the 21st century did not slow down. The convergence of wireless telecommunications and mobile computing devices ushered in the era of ubiquitous computing. The enabling technology of this new era consisted of new computing devices such as the tablet computer and "smart" mobile phones. Accompanying software innovations such as easy-to-use smart phone "apps" and cloud computing, a person could link all of one's computing devices together. The resulting everywhere - anytime access to powerful computing resources led to innovations as significant outside the workplace as inside it. The combination of telecommunications, powerful computing, and ubiquitous access ushered in the new world of social media applications such as Facebook and Twitter.

While the necessary conditions for the era of ubiquitous computing came from technological innovation, the sufficient conditions came from broader ecological system pressures. For example, changes in health care policies in the United States

motivated the development of new health care applications such as the electronic medical record and hand-held devices that allowed medical professionals to input and access data during patient interactions.

Along with ubiquitous computing came yet another reason to revisit our understanding of IS personnel. Just as e-commerce has become a regular part of doing business, social media and ubiquitous computing quickly became an important mode of communication in this era of everywhere, at all times connection. People who previously had little engagement with information technology were suddenly power users. The majority of this newest wave of potentially new IS personnel has had little formal training in the development and use of IT applications. Easier development and use is possible because the evolution of IT increasingly shields users from needing technical KSAs.

As in previous eras, the boundaries of the population of IS personnel are subject to change as new applications and organizational goals to obtain value from these applications (and related IT) change the IS task domain. We are not suggesting that all social media users will become IS personnel; however, those who have KSAs that match new organizational goals and technologies have the potential to be selected as members of the IS personnel population. As individuals outside the IS personnel population take on more of the new IS domain tasks in comparison with non-IS domain tasks, they move toward becoming part of the IS personnel population.

The jobs of IS personnel in this era continue the trend observed previously of becoming more extensive and specialized as IT evolves. Ang, Joseph, and Slaughter (2015) identify contemporary job roles and associated positions (see Table 5). In Table 6 we also list corresponding occupations, with their standard occupational codes (SOCs), that searching O*NET (US Department of Labor/Employment and Training Administration, 2014) reveals. The growing importance of outsourcing aspects of IS work is condensed within the listing of sourcing/vendor management as an IS personnel job. In conjunction with the growth in outsourcing, the consulting role (see Table 4) suggests that organizations demanding IT may rely on IT providers for more of the output from IS personnel jobs.

Table 5. Eras and IS Personnel Jobs

Era	IS Personnel Jobs
Ubiquitous Computing Era (late 1990s to today)	Information Technology Management Chief Information Officers (CIOs), Chief Technology Officers (CTOs) Project Management Project Director, Project Manager Software/Applications Development Systems Analysts, Project Analysts, Applications Programmers and Developers, Database Developers IT Service Professionals (Infrastructure) Systems Administrators, Database Administrators, Business Analytics Specialists Enterprise Architecture Enterprise Architect IT Security IT Security Architect, IT Compliance Manager, Network Security Administrator Sourcing/Vendor Management Relationship Manager, Sourcing Manager, Vendor Manager IT Sales and Marketing Professionals (in IT vendor) Sales/Marketing Manager, Account Manager, Accounts Executive and Pre-Sales Consultant Emerging Roles for IT Professionals Data Scientist (big data), Cloud Architects, Mobile Technology Expert and Mobile App Developer, Digital/Interactive Media, and Gaming, Animation (Based on Ang, Joseph, and Slaughter, in 2015)

Table 6 also compares 2014 jobs with those in 1959 as IS personnel jobs first emerged. Co-evolutionary forces have led to significant revision or elimination of several of the 1959 jobs and growth of other jobs. The contrast between 1959 and 2014 emphasizes the expansion of IS personnel jobs since their emergence.

Table 6. Contemporary IS Personnel Jobs with US Standard Occupational Codes (SOCs)

Information Technology Management
*11-3021.00 Computer and Information Systems Managers (No listings in SOC 15; CIOs and CTOs not specifically listed, but other job titles of various information systems managers included)
Project Management
*15-1199.09 Information Technology Project Managers
Software/Applications Development
*15-1121.00 Computer Systems Analysts
*15-1131.00 Computer Programmers
15-1132.00 Software Developers, Applications
15-1199.01 Software Quality Assurance Engineers and Testers
15-1199.10 Search Marketing Strategists
15-1134.00 Web Developers
IT Service Professionals (Infrastructure)
15-1141.00 Database Administrators
15-1199.07 Data Warehousing Specialists
15-1142.00 Network and Computer Systems Administrators
15-1143.01 Telecommunications Engineering Specialists
15-1151.00 Computer User Support Specialists
15-1152.00 Computer Network Support Specialists
15-1199.03 Web Administrators
*43-9011.00 Computer Operators
Enterprise Architecture
15-1199.02 Computer Systems Engineers/Architects
15-1143.00 Computer Network Architects
15-1199.06 Database Architects
IT Security
15-1122.00 Information Security Analysts
Sourcing/Vendor Management
11-3061.00 Purchasing Managers (No listings in SOC 15)
IT Sales and Marketing Professionals (in IT vendor organizations)
41-4011.00 Sales Representatives, Wholesale and Manufacturing, Technical and Scientific Products (No listings in SOC 15)
Emerging Roles for IT Professionals
15-1199.08 Business Intelligence Analysts
15-1199.11 Video Game Designers
27-1014.00 Multimedia Artists and Animators
(Based on Ang, Joseph, and Slaughter, 2015, and U.S. Department of Labor/Employment and Training Administration 2014)
* In contrast with 2014, earlier versions of mainly these jobs, with their codes at that time, comprised 13 occupations in the U.S. Department of Labor (1959) report on the emerging field of electronic data processing:
1-47.03 Supervisor, Data-Processing System
0-68.505 Project Planner, Data-Processing System
0-69.985 Systems Analyst, 0-35.77 Computing Analyst
0-69.981 Programmer, Chief, 0-69.981 Programmer
1-25.17 Console Operator, 1-25.60 Card-Tape-Converter Operator, 1-25.98 High-Speed-Printer Operator, 1-20.04 Tape Librarian, 1-36.05 Coding Clerk, 1-37.32 Data Typist, 5-83.444 Electronics Mechanic, Computer

Co-evolution patterns

Using a co-evolutionary lens highlights the relationship between two entities: IS personnel and IT. By framing the events and changes observed over the past 7 decades using this lens, we observe two main patterns. First, IS personnel and IT have adapted to each other. Changes in IT both quantitatively in its capacity and qualitatively in new hardware and software products, created a need for new jobs and an increasingly broad array of KSAs in keeping with the system principle of requisite complexity. Personnel with new and expanding sets of KSAs have been positioned to generate demand for new IT and to provide feedback regarding directions in which IT developers can and should innovate new capabilities. IS personnel also choose particular technologies in which to invest. In so doing they enact "evolutionary selection": through market mechanisms they influence technologies that will thrive and expand and those that will become extinct. Finally, they invite and discover new applications, which further broadens the base of IT and its affordances. We see this pattern existing within a context where the combination of IT capabilities and personnel with increasing amount and range of KSAs pertaining to IS provide organizations with opportunities to create value and retain positioning in their environments.

The second pattern refers to a continual change in the boundaries separating IS and non-IS personnel.

These boundaries have steadily expanded and become more permeable. We have moved from the early days of computing when individuals in a limited number of occupations with specialized technical skills formed an inner circle of IS professionals to the current state with IS personnel in a larger number of occupations having a greater variety of KSAs. (See Table 6.) Furthermore, firms have established hybrid jobs that require both IS and application domain KSAs (Wixom et al., 2011). Hybrid individuals conceptually straddle IS and a specific application domain and, depending on the organization, may move between them. With each new era of IT applications and organizational goals the IS task domain includes new tasks, e.g., web development. A number of individuals with KSAs for these new tasks initially developed and used their skills in domains other than IS (e.g., marketers doing web development). Hence, growth occurs in the number and variety of personnel performing tasks that require IS-related KSAs. The permeability of the boundaries increases as roles and emphases in individual jobs shift and personnel and jobs (e.g., telecommunications engineering specialists) transfer across IS and business functional areas.

We see a repeated pattern within each cycle. At the beginning of an era a new set of technical KSAs arises, followed by a rise in KSAs needed to construct technology that "shields" users from needing to interact directly with the technology. This is followed by a third set of KSAs needed to build supplemental tools, routines, and new applications that apply the original technology to organizational domain goals and objectives. We elaborate on this pattern and further discuss underlying mechanisms shaping the co-evolution of IS personnel and IT in the next section.

Knowledge, Skills, and Abilities (KSAs)

Where the prior section was organized chronologically by computing eras, this section is organized to address KSAs relative to countervailing forces. These forces of supply-side and demand-side pressures are addressed at the macro level, across organizations, and the micro level, within organizations.

No single categorization of KSAs captures all the studies of IS personnel KSAs. Nevertheless, to guide our discussion we refer to a broad range of KSAs for IS personnel, including technical, application domain (e.g., business, medical, or education), communication, and managerial KSAs. Different terms may be found in the literature. There are studies that refer to "hard" instead of technical skills, and interpersonal or humanistic, instead of communication and managerial skills. Some studies use fewer categories, such as technical and soft (Litecky, et al., 2004). Others may use more detailed categories, such as operating systems, programming languages, networks/communications, software development tools, and non-technical (including communication, interpersonal, leadership, organization, self-motivation, creativity, and other (Gallivan, et al., 2004)). Yet other studies recognize that KSAs differ across IS personnel. Some of these studies clearly distinguish IS managers (Cheney, 1988) and management-based KSAs from others. For example, Kaiser, et al. (2010) refer to project management skills, while Todd, et al. (1995) refer to general management skills. Clearly, KSAs for IS personnel have been widely studied (see Lending and Dillon, 2013; Stevens, et al., 2011; Kaiser, et al., 2010; Lee & Wingreen, 2010; Litecky, et al., 2010; Huang, et al., 2009; Litecky, et al., 2004; Nakayama & Sutcliffe, 2001; Lee, et al., 1995; Todd, et al., 1995; Nelson, 1991; and Cheney, 1988).

Individual organizations have their own histories of co-evolution of IS personnel KSAs and IT. IS personnel shape IT specifically within their organizations and are shaped by IT and the organizational users of IT. IS personnel use their technical, application domain, communication, and managerial KSAs to select, install, and adapt the technology to the local site and support the user community. Through the processes of selecting, installing, adapting, and supporting IT locally, IS personnel within the organization supply IT to users in the organization, thereby shaping IT locally. In turn, IT locally selected, installed, adapted and supported shape the IS personnel of an organization. The supplied technology influences the KSAs needed by end users and IS personnel. This organization-specific co-evolution of IS personnel and IT is the local (i.e., micro) analog of what occurs at a macro level between IT provided by supplier organizations and organizations that demand IT. We examine two strong countervailing forces driving this co-evolution next.

Countervailing Forces

We see two intense forces pulling in separate directions regarding the co-evolution of IS personnel KSAs and IT. One force leads to an increasing need for new technical KSAs with the emergence of each new technology. This force is the drive for innovation by both suppliers and users. It generates new technologies, new uses for existing ones, and modification or extension of existing technologies to enable innovative applications. The other force is based on an underlying economic drive to reduce the cost of using technology. It is manifested in a drive to require fewer or lower technical KSAs to use IT. We explain how these forces play out in the discussion below.

Supply-Side and Demand-Side Pressures for New KSAs and IT

IT suppliers are driven by the interests of their technology designers, competitors, and users to innovate, i.e., develop new IT. The force of waves of technological innovation breeds burgeoning new technical KSAs. Clearly there was no need for PC KSAs before PCs were invented or for webmasters before the internet was created. With each new technology from suppliers, KSAs pertaining to the deployment, maintenance, and exploitation of that technology become needed. As already noted, this trend is consistent with the law of requisite variety (Ashby & Goldstein, 2011) and the principle of requisite complexity (Benbya & McKelvey, 2006), whereby more complex environments demand additional system complexity to remain effective. As stated by Vessey and Ward (2013), “when an organization adopts a new technology, it must either hire new personnel or retrain existing personnel to increase the internal ‘variety’ of technology knowledge available to match the ‘variety’ of knowledge in the external environment.” We illustrate this force for new technical KSAs during two different eras of technical innovation – the end user revolution and the e-commerce gold rush.

At the start of each new era of emergent technology, a new set of KSAs proliferate. Consider, for example, relational database management systems (DBMS) that emerged in the 1970s (Darwen, 2012), fueling the end user revolution. Organizations adopted these technologies and IS personnel developed KSAs to support and use them to such an extent that there are now specialized jobs in the database area. Jobs such as database administrator and database architect (O*NET OnLine, 2012a) did not exist prior to the invention and adoption of these technologies. Similarly, in the e-commerce gold rush era KSAs proliferating from an emergent technology are observable in the jobs associated with web-based technologies. Jobs such as web developer and web administrator (O*NET OnLine, 2012b), which fueled the e-commerce gold rush, did not exist prior to the invention and adoption of the internet and related technologies by a critical mass of organizations and individuals. Clearly, new technical KSAs are required to succeed in these jobs.

New and evolving IT leads to a need for new KSAs which address emerging specialized roles. These also lead to the need for new and updated technical KSAs. In the early days of DBMS applications, the need emerged for technical KSAs simply to create connections between tables and retrieve data into reports. As vendors of DBMS (e.g., Oracle and IBM) updated the underlying technologies through cycles of new versions, new technical KSAs were required to understand and implement the new features. Examples of updated technologies that require IS personnel to update their technical KSAs relative to the broader domain of databases include new storage devices, middleware, security and compliance, enterprise systems software (ESS), data marts and warehouses, embedded databases, and object oriented databases. IS personnel working with DBMS have also found it appropriate to understand the nature of the data and how it is used to support organizational processes. This may have required the development of application domain and communication KSAs. However, as user organizations influence IT suppliers to lead to new technology developments (e.g., menu driven interfaces and data cubes and snowflakes), users receive greater shielding from technical details, allowing them to concentrate on application of database content to organizational problems. Thus, the co-evolution of IS personnel and IT potentially pushes the development of new application domain skills and shifts tasks that demanded technical KSAs, such as programming in SQL, into demand for application domain, communication, and managerial KSAs.

Similar observations occur when considering web technologies. As websites grow larger and move from static to dynamic capabilities, newly emergent technical skills include installation of supplemental programs (add-ins), development of applet and servlet processing, tuning of web server performance, and optimization of network traffic. At the same time the upgrade of technology creates demand for new application domain KSAs pertaining to making more and different content available, building more sophisticated interfaces, and shifting from text to graphical representations in the service of making sites more valuable and easy to use for consumers. As firms expand their web activities, we see differentiation between IS personnel focused primarily on the operations of the web presence and those concerned primarily with content. In many cases the customers are not organizations but individual consumers. To serve consumers, developers of web applications, with related technical KSAs, are adapting the IT they provide (viz., web applications) to make it possible for the end users/consumers to personalize the web applications (Brossad, Abed, & Kolski, 2011) with little or no technical KSAs.

The extent of innovative use of IT in demand-side organizations is another manifestation of the influence of innovation on the co-evolution of IS personnel and IT. Organizations that have "bridgers" possess a foundation for innovation via IT that could enable them to compete effectively using IT. We refer to IS personnel who extensively provide linkage between IT and the business domain as "bridgers." [4] These IS personnel, often titled "business analyst," report through an IS function or through a business functional area. However, they are primarily engaged in the translation of technical capabilities into domain applications, in contrast to end users engaged almost exclusively with business domain activity, even as they use systems provided by others.

The extent of innovation via IT is unevenly distributed throughout the competitive landscape and is evident in organizations having different information system strategies (Chen, Mocker, Preston, & Teubner, 2010). A key application domain KSA in this regard is the ability to understand the value or potential competitive advantage of a specific IT. Application domain KSAs supplemented with communication and managerial KSAs are needed to more fully leverage IT to obtain the understood value or competitive advantage. These additional skills are needed to influence and manage organizational innovation that involves adoption of IT and leveraging it for competitive advantage. Those workers with the ability to communicate a technology's value or potential competitive advantage can influence others in the organization to adopt the technology. Projects typically serve as a venue for adopting innovative IT. Thus, IS personnel expected to manage such projects should have not only communication KSAs but also change management (Markus & Benjamin, 1996) and project management (Starkweather & Stevenson, 2011) KSAs.

To leverage IT to provide organizational value, individual managers, whether working within or outside the IS functional area, must first develop their KSAs for identifying and understanding innovative uses of IT, which provide such value. As Swanson (2012) suggests, managers need to carefully evaluate which IT innovations they should implement to gain value. Being educated about information technologies should help managers throughout an organization identify and adopt innovative, complementary uses of technology to provide strategic support to organizational processes, with the goal of positively influencing the organization's competitive position (Ross & Weill, 2002; McAfee, 2006; Atkins & Galliers, 1992; and Stone, 1980). They could also work with IT suppliers to develop innovative IT (McKenney et al. 1997).

The KSAs of the top manager of the IT function (i.e. CIO) depend on the strategic level of the IT function and, simultaneously, the role of IT in the competitive strategy of the organization (Stephens, et al., 1992; Weiss, et al., 2006). For organizations in which IT plays an innovative, strategic role, the CIO is a member of the top management team and is responsible for bridging IT and other senior executives as well as aligning the organization's strategy and information technology resources. Knowing how to influence executive peers and successfully exhibiting such behaviors, particularly for strategic information systems projects, are critical KSAs of a CIO (Enns, et al., 2003). Not all IS personnel are expected to have the KSAs of a CIO. Nevertheless, the bridging role extends from the CIO to those at various managerial levels, to those without formal managerial responsibilities but nevertheless responsibility for contributing to project success or successful change efforts.

The examples and discussion above illustrate a pattern of mutual influence of IS personnel and IT. New IT affects KSAs of IS personnel. IS personnel respond to new technology by: (1) assimilating new KSAs to adopt and integrate these into organizations; (2) developing applications that utilize these technologies; (3) developing "shielding" in the form of interfaces and procedures that allow users to take advantage of technology affordances without needing to interact with the technology at a level that requires technical KSAs; and (4) guiding and enabling a transition for some end users to specialize in the adaptation of the technology to new domain applications. As a result of these direct actions, IS personnel, end users, and "owners" of the systems (e.g. those who sponsor the technology without personally interacting with it) create new opportunities for extending technical capabilities. They

[4] Others have referred to systems analysts as bridging the gap between technical and business aspects of information technology (Lichtenthal 1994) and, similarly, CIOs as bridging the gap between the technical and business objectives of the organization (Dawson and Watson 2011).

also help shape the direction of new technical development, whether incremental upgrades to technology or disruptive new technology. The end result is mutual influence.

Pressure to Reduce Technical KSAs

Over time, we see the development of increased “shielding” so that users of IT may reduce the need for mastering technical KSAs to apply the affordances of IT technology to their domain-related applications. When the number of individuals or organizations using a specific IT is large enough to influence the providers of the IT, a critical mass stimulates a demand for features which are not being provided (or not in the manner or magnitude desired). Based on the influence of this critical mass, providers will make one or more changes to the IT in terms of functionality, form, performance, price, or provider support. To a large extent this dynamic follows a feedback loop whereby IS personnel and application domain users can signal opportunities for vendors to shape their technology to meet user needs. The erosion of a critical mass also has an influence, with the ultimate influence being the eventual abandonment of the IT by suppliers and users. Consider, for example, the rise and fall of punch cards and keypunch machines (PCMAG.COM Encyclopedia, 2012).

An example of this pressure is apparent in changes in the technical KSAs needed to conduct data analysis. In the “Computing Inner Circle” era, prior to the existence of spreadsheets, non-IS individuals wishing to conduct data analysis would need to engage someone with programming skills to design and perform the kind of data analysis desired. In the end user revolution era spreadsheets made it easier to adopt and use IT to conduct a variety of data analyses that would provide value to a large number of individuals at a relatively low cost. Campbell-Kelly (2007) investigated the evolution of spreadsheet usability from VisiCalc through Lotus 1-2-3 to Microsoft Excel. He reports that the spreadsheet program was shaped by the providers responding to the preferences of the market, i.e., a critical mass of users. Compared to earlier IT that required programming skills, this IT requires a relatively low level of technical KSA and provides value to “tens of millions of users who [have] little or no direct computer experience” (Campbell-Kelly, 2007). This and the examples of database and web technologies are but a few of many instances of technology providers being influenced by a critical mass of organizations or individuals to change IT to make it easier to adopt and use.

Just as most car drivers are not mechanics, most users of IT are not technical experts in supporting the IT they “drive.” Similarly, we would argue that most organizations on the demand side prefer to invest as close to 0% as possible of their resources in technical KSAs and, instead, invest them in other KSAs (e.g., application domain KSAs) that facilitate obtaining value from IT. CIOs of these organizations worry about aligning IT with organizational strategy (Luftman & Derksen, 2012). They anticipate that their organizations derive value from spending time on application-domain-based rather than technical activities.

Although new technologies drive the need for new technical KSAs, making some KSAs obsolete (Glass, 2000; Zhang, et al., 2012), we also see that with each era, the countervailing force of organizations and individuals desiring easy-to-use IT leads IT suppliers to provide IT that requires fewer or less complex technical KSAs by end users at its inception. For example, in the ubiquitous computing era, text messaging became pervasive in many quarters of society before firms could assimilate it into their working communications environment. The procedure (or user task) to perform text messaging was obvious to any consumer. However, integrating this capability into an organization meant dealing with issues such as scalability, security, governance, and integration with other technologies. From the user perspective, this transformative technology was available “out of the box” but for organizations the underpinnings and perhaps in some cases the integration with business processes had to be engineered

Implications for Curriculum

As computer-related work has moved from centralized mainframe-oriented operations to ubiquitous distribution of processing, a wave of research regarding IS personnel development has also occurred (Igbaria & Shayo, 2004; Lowrey & Turner, 2007; Niederman & Ferratt, 2006; and Yoong & Huff, 2007). Hirschheim and Klein (2012) recognize model curricula for academia to support more clearly the education of IS professionals in order to meet the needs of industry during different eras. These evolving model curricula acknowledge a continuum of jobs from those that involve direct interaction with IT to those that focus on applications of IT in a particular domain (e.g., Topi, et al., 2010; Gorgone, et al., 2003). Further, they are challenged to strike a balance between further differentiation of more specialized positions and focusing on core lessons that all IS personnel need. In this section we consider eight trends that are influencing, and will continue to influence, IS curricula in academia.

Eight Trends Influencing IS Curricula

Using the co-evolution lens, we expect eight trends to influence IS education and curricula. These trends revolve around a growing continuum of IS jobs, the need for both technical and non-technical KSAs, and ever easier access to information technology through technology shielding and the creation of new applications. These trends affect both current and future IS personnel. Awareness of these trends is important for educators as they position their students for career entry and life-long learning. We also identify two ways to address these curricular challenges: adjusting administrative structures and expanding industry collaboration.

The first trend is that new technologies, jobs, and the consequent need for new KSAs grow faster than old ones drop away. As a result, even if a newer disruptive technology initiates a new era, the need to retain technology KSAs through maturity and even into legacy status continues. For some entrants into the IS field this will represent a longer shelf-life for their KSAs and total value of investment in their development. Others who thrive on change will have many opportunities to leverage existing skills to new technologies. As a result, educators will need to continue support for some important older technologies as they plan the transition to emerging ones.

Second, the continuum of IS jobs and the range of KSAs needed for them will continue to expand. Whereas education for IS practitioners may have been concentrated in relatively few academic areas during the "Computing Inner Circle" era, the future will see an increasing number of academic disciplines contributing to IS knowledge. Though engineering and computer science programs may focus most tightly on traditional technical KSAs, increasingly they are called upon to add communication, ethics, and other so-called "soft skills" to their curricula. Task domains, such as accounting and health care, are adding IS components to their programs to develop accounting information systems and health informatics specialists. Building IS specialists within their communities will enable them to assist their end users to assimilate new variations on procedures more quickly, state information requirements more clearly, and report opportunities for innovation more adroitly. The implication is that educators face an increasing pressure to expand their educational offerings to serve the expanded need for KSAs. Although some educational institutions may be able to take advantage of expansion opportunities, others may be constrained by the cost of expanding their programs.

Third, sustaining educational programs that address the entire continuum of IS and hybrid personnel will become increasingly difficult. The one exception might be in the emergence of information schools that house computer science, information systems, and often additional programs like library science. The potential exists for such schools to fill gaps between traditional knowledge domains. They can offer integrated content to students ranging from direct manipulation of complex technology to nuanced application in end-user domains. An implication of the difficulty of sustaining a broad educational program is that educational institutions should target segments of IS personnel, existing hybrids, or projected new hybrids based on emerging IT. They should tailor curricula and support activities to a well-articulated but narrower range of students in each segment. Those educational programs that have not purposefully selected a target segment may find themselves more and more stretched and less able to define clearly who they serve and what they provide. Shifting to a more targeted approach can be difficult, though, as it implies ending support for a segment of the continuum that is small but valued.

The fourth trend is that the common categorization of IS KSAs as technical, domain (e.g., business), communication, and managerial are no longer isomorphic with jobs along the continuum. Personnel across the continuum of jobs all require KSAs from each of these categories. To illustrate, technical jobs, for example designing and maintaining infrastructure, primarily require technical KSAs but also need a specialized subset of non-technical KSAs such as mentoring and training others, documenting implemented solutions, and explaining or promoting particular technical investments. At the same time the most user-oriented jobs requiring primarily domain, communication, and managerial KSAs, also need technical KSAs for security, backup, capacity planning, selecting alternative implementation tactics, and the like. The implication of this observation is that those educational institutions focusing on segments of the continuum cannot optimally target only traditionally technical or traditionally non-technical KSAs but also need to find the combination appropriate for that particular segment.

The fifth trend is that many organizations, even while experiencing shortages of IS personnel, have reduced the amount of training and development they provide to their staff. Ferratt, et al. (2005) show that the investment in training varies with the intention to retain staff. Organizations with a low investment strategy release staff members and replace them frequently with newly educated workers. This puts a double strain on universities to provide "cutting edge" knowledge that the low investment firms will be looking for while also providing strong fundamentals that the high investment firms can then customize for application in their own enterprises. The implication of this observation is that universities will have to increase both immediately applicable KSAs and KSAs that form a base for long term growth. Alternatively they will focus exclusively on either short or long term KSAs, thus positioning graduates for organizations of one or the other personnel strategy. This distinction may not be easy to communicate to potential student recruits or to organizations looking to hire entry level graduates.

The sixth trend is a continued movement by demand-side organizations to outsource jobs and tasks primarily from the technical side of the KSA continuum. This is a natural outcome of specialist outsourcing vendors being able to achieve benefits from larger scale and more specialized staffing. It is also a natural outcome of the desire for business people to focus more on domain activities than the technical details of the IS that support them. However, the most domain-oriented companies cannot shed all interaction with and responsibility for the technologies that support their operations. As Lacity and Willcocks (2001) point out, organizations need to be mindful of retaining key IS-related KSAs. These KSAs involve vendor relations, strategic information needs, and incorporation of new technologies, as well as tools to extract the maximum value from available technology in the service of organizational purposes. Organizations also need to monitor and support the computer-related activities of their domain staff members who rely upon technologies but interact with crafted interfaces to shield them from technical detail. An implication is that IS educational programs located in business schools may want to particularly target those jobs and KSAs along the continuum most likely to be retained by organizations when all else is outsourced. Educators who offer programs that develop the KSAs of managers, both IS and non-IS, as well as end users, for identifying and understanding innovative uses of IT should find a niche with those organizations with a strategic focus on innovative use of IT. Training and development of IS personnel, particularly bridgers, in project management (Starkweather & Stevenson, 2011) is driven by a need to develop KSAs that will support change management in project settings, for example.

Seventh, given an expectation that new technologies will continue to emerge, the need for shielding will continue. This need is also prompted by the continued objective of cutting or managing costs. The use of self-service technologies (SSTs) provides an example of such shielding that enables organizations to interact directly with customers, reducing the need for tool specialists. Examples of SSTs that organizations have provided to customers are automatic teller machines (ATMs), interactive voice response units (IVR/VRU) and web-based self-service portals (Kumar & Telang 2012; Yankee Group, 2006). SSTs also allow an organization to do more with less since the work load is being shifted from organizational members to customers. Being challenged to do more with less is not uncommon for IT executives. In reporting on the 2008 SIM survey, Luftmann, et al. (2008, p. 157) note, "As in previous economic downturns, the greatest challenge for managers is to do more with less. CIOs need to work with their staff and business partners to evaluate priorities while ensuring IT delivers value." The implication is that educational institutions may anticipate such formalization of this "shielding" role and develop programs to address customized skill sets that facilite entry level and more advanced practice of KSAs associated with this role.

The last trend is globalization. Both provider and user firms will extend their global reach and include personnel from many countries. Provider firms will expand from solely producing new hardware and software to increasingly providing consulting with respect to IT selection, customization, and management. Vendors both large and small will provide applications for local markets as well as adapting applications for local customization around the world. These trends will continue to increase the range of people working in IS and add new specializations, such as local site project coordinator and virtual team architect within the broad "vendor management" umbrella (see Table 5). The implication of this observation is the expectation of new educational programs that specifically address this growing area and the development of increased sensitivity to cultural diversity and localization both for supporting distant multicultural teams and for responding to increasingly diverse domestic workforces (Koh, et al., 2009; Koh, et al., 2010).

Beyond these trends and their immediate implications, IS educators could follow two different paths. First, they could experiment with changes in organizational structure needed to keep up with the pace of co-evolution. Such experiments might involve the integration of professional skill building with more traditional education. Longer calendar periods of school attendance could be punctuated with periods of internship and other on-site skill building activity within organizations. Similarly, experiments might involve shifts in educational delivery that emphasize students and instructors learning new technology together in designing and implementing innovative products. For example, instructors may integrate the basics of programming as students design and build new mobile apps while educators provide reflection, generalization, and broadening of the lessons from such activity.

Second, educators could redefine relationships with industry in various ways. They could invite organizations to bring real problems to the classroom setting. Students could visit and participate with organizational professionals in mentorship relationships. Of course, the specification of these activities is likely to vary with the preponderance of industries in a particular geographical location and with the relative enthusiasm of leaders in particular firms. None of these sorts of activities is without precedent, but IS educators could invite broader and more pervasive interactions to address some of the challenges faced by organizations seeking to acquire or develop their IS personnel.

To institute such innovations, educational institutions will require the active participation of industry partners. However, educational institutions may need to take the lead in selling such programs to local organizations as well as structuring, administering, and adjusting such programs as needed. In addition to their undergraduate and graduate degree offerings, academic institutions can supplement those with non-degree programs, including continuing education and industry certifications. Academic institutions could tailor non-degree programs to targeted KSAs as a way of complementing academic offerings.

Because distance learning in all of its manifestations addresses the full range of educational topics, including but not limited to IS KSAs and other skills aimed at IS workers, we have not addressed this topic at length in this essay. Similarly, the emerging presence of massive open online courses (MOOCs) and their cousin massive open online resources (MOORs) (differentiated by being either organized elements of programs delivered or being completely student obtained) offer the potential for significant change in the delivery of training modules that may affect any profession. Given the rapid rate of change related to KSAs in IS, these approaches might be a logical target area for emergent programs based on these technologies. University IS programs may be uniquely positioned to experiment with building such systems and incorporating them into the fabric of their content delivery. Organizations have the opportunity to cobble together modules to customize and expand knowledge among their staff wherever they may be on the continuum from those directly interacting with the insides of technology to those applying shielded tools in their domain of interest.

Addressing the IS Growth/Demise Paradox[5]

Running alongside curriculum implications for developing IS personnel is a troubling paradox: how can claims about the need for an increased number of IS personnel (e.g., Committee on Workforce Needs in Information Technology, 2001; Freeman & Aspray, 1999; Panko, 2008) be reconciled with data and predictions about the demise of the IS field (e.g., Firth, et al., 2011)? Our examination of the co-evolutionary history of IS personnel and IT provides some clues. Relevant trends include steady increase and progress in both IT and the differentiation and sophistication of the community of IS personnel.

As the set of people working with computing technology continues to grow, the term “IS personnel” will refer to a complex and growing set of people with evolving roles, duties, and KSA requirements. IS personnel can be categorized into at least four subsets. These are: (1) technical specialists – those who work with and are directly concerned with the operation of new and evolving technology, characterized by infrastructure and computing architectures; (2) domain specialists – those who do more than use IT to effectuate pre-defined tasks, but help to evolve the IT to a larger range of tasks and more effective operations; (3) “bridgers” – those who are concerned primarily with sophisticated IT, their capabilities and affordances, and their application to domain purposes, and (4) IS managers – those at various levels within and across the three previous categories who are responsible for IS managerial functions.

In our view, the growth/demise paradox follows from three sources. One is the subsets of IS personnel described above. The second is the variation among organizations employing IS personnel (supply side and demand side). The third is a difference in views about the co-evolution of IT and IS personnel that each vision encompasses. The vision of an increased need for IS personnel arises from looking simultaneously at all subsets of IS personnel in both supply-side and demand-side organizations. This vision is based on forces driving co-evolution, including both the search for innovation and the desire to reduce costs of and need for complex technical KSAs. The vision of a decreased need for IS personnel arises from looking narrowly at the subsets. Observers with this narrow vision will see a diminished need for IS personnel as more technically oriented individuals drift toward provider firms and come to increasingly resemble those in computer science and engineering roles. At the same time, those in user firms outsource or “send to the cloud” more of their technically-oriented work. Others will not recognize IS workers among those performing development and maintenance tasks but who are resident in domain/ functional areas.

IS educators face a policy and pragmatic question as to whether they should expand their programs to address IS personnel moving toward either the more technical or the more end-user orientations, whether they should focus on “bridgers,” or whether they should include offerings for IS managers. They could concede education of the more technical topics to our colleagues in computer and information science programs.

[5] We use the term "IS Growth/Demise Paradox" based on Firth et al. (2011). This paradox is not to be confused with the IS Productivity Paradox (Brynjolfsson 1993), which addresses the problem where the effects of IS on productivity are visible all around us, but positive and negative gains from IS tend to cancel each other out in formal economic input-output studies.

They could leave more domain oriented topics to IS oriented specialties within specific domains of study, e.g., accounting (accounting information systems), art (web design), health (health informatics) and government (e-government). Demand for knowledge transfer across the whole range of IS personnel, regardless of originating source of such education, will continue. Specialists in IS education will want to consider carefully their targeting of broader or narrower segments of IS personnel based on their resources, their local demand, and their ability to deliver and demonstrate the value of their offerings.

We offer some additional thoughts regarding this paradox. When practitioners refer to a shortage of IS personnel they may be referring to gaps in particular skills. This is likely a result of the short time period over which new transformational technologies emerge, resulting in a sudden increase in demand for technical skills not yet addressed by educational programs. The shortage of IS personnel may also refer to their availability at a particular price. Those who have mastered KSA sets pertaining to established technology may have moved through rounds of raises and salary growth. As a result it may prove less expensive to train a newcomer entering at a lower salary rate than to retrain an already higher paid expert moving from a technological knowledge base facing extinction. Even when masters of older technology can be retrained or transferred to a new technology, this may leave a gap in coverage of legacy technologies that are still in use. As a result, the transfer of personnel from one “era” of technology to the next may lag. It is also likely that at the dawning of a new era it is difficult to determine which of the legacy skills will simply transfer to the new era and which will become obstacles to the required new mental maps for mastering the emergent skills. One of the implications of moving increasingly away from an inner circle of IS personnel and into new task domains with newly emerging IT, is an increasing fuzziness in knowing who does and does not fit under the heading of “IS personnel.”

To further illustrate how imprecise definitions of skills, such as “technical” or “managerial,” contribute to this lack of clarity, we also need to consider the issue of balance. The most technical infrastructure architect is likely to need “managerial” skills regarding the understanding of the organization’s business needs and priorities as well as “communication” skills to explain tactics and procedures as well as delineate documentation. The application domain analyst is likely to need “technical” skills to set up efficient, repeatable queries. Thus, those performing “technical” jobs will require a preponderance of technical skills, but not be isolated from needing other skills, such as some managerial and communication skills. Similarly those performing “application domain” jobs that heavily use computing will require predominantly application domain skills but not be isolated from needing other skills, including a measure of technical skills. As a result, our understanding of both jobs and skills and how they are combined as targets in educational programs can be more nuanced than simple technical/non-technical dichotomies. Achieving the right balance of technical and non-technical skills within an educational program will depend on what sort of occupations along the technical—bridger—application domain spectrum as well as the spectrum of management positions are targeted.

This paradox can also be explained, in part, from cycles of short-term shortages in key roles and eventual “gluts” in others. The realities of academia with limited budgets for new technology and institutional reluctance or inability to embrace rapid change make it difficult if not impossible to address quickly each new emerging technology. One approach is to focus academic programs on computing “fundamentals” that can be applied to both emerging and stable IT. However, this tends to leave a gap between graduates and immediate application of the most up-to-date KSAs. In business schools this is also likely to result in greater emphasis on stable KSAs such as methods for evaluating new technology, project management, assessing risk, and interacting with vendors. Doing so not only tends to deemphasize more technical KSAs, it also moves toward overlapping skill areas taught in other disciplines including management, operations, and accounting. The result is that it becomes more difficult to define exactly what IS consists of and how it differs from other fields.

Following this line of thinking does not provide one simple “answer” to the paradox, but does suggest some alternative strategic targets for university programs. Some programs may be able to develop an infrastructure to absorb changing technologies approaching the rate at which they change in the business environment. This might necessitate new institutional structures, such as incorporating into an IS curricula internships (Trauth, et al., 1993) or coursework provided at organizational sites. Institutions following this route may need to work hard to insure that the results provide broad education and not just rote training. This scenario would also necessitate organizations taking some risk by exposing their efforts at cost savings and innovation to outsiders. It might also involve some cost in terms of time and energy needed to implement such a program and risk in terms of the potential for student errors to disturb ongoing operations. It may also require the discipline to disband programs as technologies mature, even if such programs remain profitable, in order to refocus resources on newer emerging technologies.

Information schools that integrate computer science and IS might be in a stronger position than business schools to address the entire KSA continuum. The reach of such programs may be from the most technical IS personnel through "bridgers" without particular concern for whether such KSAs are applied in supply-side or demand-side organizations.[6] Another alternative is to focus on particular widespread tools. We see this emerging with the growth of focus on enterprise systems such as SAP as a specialty in some business schools. Challenges here include selecting emerging tools early enough to gain relevant expertise in the assimilation stage and picking ones that will remain in active use long enough to recover investments in tools. Tools such as enterprise systems have the positive attribute that even if the first wave of implementation among pioneer firms is missed, the slow diffusion across industries and firms assures much on-going activity over a significant period of time. It also suggests a long lifetime given the installed base of users and the costs of shifting to alternatives. A third alternative would be to focus on adding to the tool-using capacity of domain-related fields. We see this with the widespread growth of Health Care Informatics and similar programs. Challenges here include issues with trying to address too broad a range of KSAs. Many health care educational programs have their own IS or informatics curricula and may or may not want to outsource some of the teaching to IS education specialists.

Conclusion

In this essay we have presented an in-depth examination of the co-evolution of IS personnel and IT.[7] We have noted a number of patterns and identified some underlying mechanisms shaping this co-evolution. We did so by taking a long-term historic view of the field. Following the admonition of Land (2010), the lessons of history are not always simple or easily accessible. Although we remain very close to recent technologies such as mobile, cloud, and social network computing, when viewed as extensions of older patterns of emergence and institutionalization of new technology, we believe we can draw lessons from even recent history. In that spirit we conclude with summarizing the key findings that emerged from this study.

We found that historical patterns of progress, cycles, and persistence supplement our understanding of the co-evolution of IS personnel. We noted progress via the increasing inclusiveness of who may be considered IS personnel with a continually increasing breadth and range of technical, application domain, communication, and managerial KSAs related to IS personnel work. We described cycles of emerging technology initiated by incremental or disruptive changes in technology followed by an eruption of needs for new technical skills, the development of "shielding" around the technology to reduce the technical KSAs of application-domain users, and movement toward additional application of the once-new technology as it becomes increasingly available. Important aspects of persistence were discussed, including the need across emerging IT cycles for skills pertaining to innovation, change management, and integration of new IT into the existing IT portfolio.

The underlying mechanisms shaping the patterns of co-evolution emerge as two major forces. One is a drive for innovation. It arises from supplier firms and those demanding new technology, all of which may be located throughout the world. The other is a demand for lower cost IT that becomes progressively easier to use over time. Ideally, application domain users will be shielded from the technology such that their need for technical KSAs decreases.

We view those responsible for the IS personnel workforce and for preparing its new entrants as key stakeholders in applying the lessons of history pertaining to IS personnel. Trends suggest no long term decrease in the need for technical, application domain, communication, and managerial KSAs, but educators face potential changes in how to serve specialized audiences of (1) technical specialists (with greater focus on technical KSAs), (2) domain specialists developing and managing local IS applications (with greater focus on domain KSAs), (3) "bridgers" (with a mixed focus on integrating technical and domain KSAs), and (4) managers at various levels.

[6] An example is the Information Sciences & Technology degree offered at Penn State University. Three undergraduate options are available to students. Option 1 aligns with the technical specialist, Option 2 aligns with the "bridger"; and Option 3 aligns with the domain specialist.

[7] Future researchers might want to consider whether such co-evolution can be better explained by considering additional entities, such as the end user and/or general market pressures. We do not know of models for co-evolution of more than two entities, but we also know of no reason that more than two cannot interact to create observable outcomes.

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