Communications of the Association for Information Systems

Volume 33 Article 26

12-2013

A Theoretical Framework to Develop a Research Agenda for Information Systems Innovation

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Abstract:

This article is a response to the assessment by IS scholars that there are significant research questions to be addressed in the important topic of information systems innovation. For example, Swanson concludes that current theory explains little about IS innovation; Avgerou describes it as a relatively unexplored subject, and Fichman identifies signs of exhaustion in the current research agenda. The result of our analysis is an adaptation of ecological systems theory (EST) in order to apply it to the IS innovation landscape. We then build on the theoretical framework to propose an agenda for future research in terms of research directions, research themes, and study designs. Finally, implications for researchers and practitioners are discussed.

Keywords: information systems innovation, theory, ecological systems theory, research agenda

Volume 33, Article 26, pp. 443-462, December 2013

Communications of the Association for Information Systems

I. INTRODUCTION

The central thesis of this article is that a new theoretical framework is required to enable researchers to successfully navigate the challenging terrain of *information systems innovation*. The study is a response to the assessment by IS scholars that there are significant research questions to be addressed in this important topic. For example, Swanson [1994] argues that the innovative deployment of information technology is "increasingly crucial to competitive survival and success" (p. 1069), but laments that current theory explains little about IS innovation. Fichman [2004] has diagnosed signs of exhaustion and has called for researchers to seek out more radical concepts to revive the study of IS innovation. This, he contends, is due to the dominant paradigm of "economic rationalistic models" reaching the point of "diminishing returns" (p. 315). Meanwhile, Avgerou [2002] comes to the surprising conclusion that the term *innovation* is not extensively used in the information systems literature. Elsewhere we have argued that recent major technological disruptions, such as the diffusion of self-service technology (SST), have altered the information systems innovation landscape [Costello and Donnellan, 2007]. Importantly, the conclusion of the recent *WEF Global IT Report* is that ICT "matters a lot" for innovation [Osorio-Urzúa, 2008]. An analysis of the literature suggests that research in innovation within the IS world would profit from an ecological approach. For instance, Swanson and Ramiller [2004] call for attention to the broader institutional context and exploration of the psychological literature. Fichman [2004] asks researchers to adopt more radical concepts, while Avergou and La Rovere [2003] exhorts the community to challenge established categories and divisions in the area of IS innovation. Similarly Crowston and Myers [2004] call for IS research to encompass economic and cultural perspectives, while Markus [2004] argues that history and time are important factors. Specifically, Lee [2001] uses the analogy of an ecosystem to conceptualize the notion of an information system. In a review of the wider innovation literature, Wolfe [1994] concluded that the prolific growth in innovation publications had made little contribution to the understanding of innovative behavior in organizations, and the results presented were largely "inconclusive, inconsistent and characterized by low levels of explanation" (p. 405). More recently, Fagerberg's [2005] assessment that our understanding of how innovation operates at the organizational level is still fragmentary and "that further conceptual and applied research is needed" indicates a scarcity of progress in the intervening period (p. 20).

This article seeks to address the following research question: How can ecological systems theory enable the development of a research agenda for information systems innovation?

The study proposes that ecological approaches have the conceptual structures to assist researchers because they meet the criteria implicit in our research question and have a proven track record in organizational theory and social psychology. The framework that we build on is that of ecological systems theory (EST), which provided a new perspective for research in human development when it was introduced by Urie Bronfenbrenner [1979]. This article translates the theory into the IS context and elaborates Bronfenbrenner's schema by developing a specific *EST for IS innovation* because the technological dimension is missing from the existing framework. The benefits of the new framework include providing a fresh perspective for researchers to investigate the phenomenon, integrating the complexities and deficiencies identified in the literature, and presenting information systems innovation as a dynamic interactive process resulting from the encounter between people and their environment with its technological capability.

The plan of the article is as follows. The first section will provide an overview of research in order to present the arguments and criteria for a novel ecological framework. Following this we will engage with a number of prominent ecological theorists and present the case for the suitability of Bronfenbrenner's work for the IS domain. That section of the article will also include a presentation of the *EST for IS innovation* framework and explain why it makes a contribution to the discipline. Finally, we build on the theoretical framework to propose an agenda for future research in terms of research directions, research themes, and study designs.

II. BACKGROUND

The general innovation literature is voluminous and eclectic, and a comprehensive review is beyond the scope of this study. However, this section will provide a brief overview in order to support the main argument of the article: that an ecological lens is required to navigate the "information systems innovation" body of literature.

Innovation: A Very Short Introduction

Many scholars trace the introduction of innovation into the realm of economic and social change to Joseph Schumpeter's seminal work [1934] *Theorie de Wirtschaftlichen Entwicklung* (*Theory of Economic Development*). Schumpeter's writing spanned a period of forty years from his undergraduate days in the University of Vienna to his term as professor of economics in Harvard [Oakley, 1990]. According to Marz [1991], he is one of the few social scientists who bequeathed an "intellectual legacy that continues to attract new generations of students, teachers, scholars and politicians" (p. xv). Innovation together with bank credit, according to Schumpeter, are the economic mechanisms "that define a large part of the history of mankind" [Oakley, 1990, p. 15]. In his *Theory of Economic Development,* he classified innovation into five categories: new products (or goods), new methods of production (or processes), new sources of supply (or half-manufactured goods), the exploitation of new markets, and new ways to organize business. In Schumpeter's original schema, innovation is accomplished by "entrepreneurs" who developed new combinations of existing resources [Swedberg, 1991]. However, in his later works, he came to regard the large corporation as the innovative engine driving the development of leading economies [Lazonick, 2005]. The *Harvard Business Review* collection of seminal papers on enterprise innovation begins with the theme of creativity [Amabile, Hadley, and Kramer, 2003]. Here the authors suggest that time pressure affects creativity differently depending on "whether the environment allows people to focus on their work, conveys a sense of meaningful urgency about the tasks at hand, or stimulates or undermines creativity in other ways" (p. 14). Min Basadur endorses the creativity equation, C = K x I x E, developed by Parnes, Noller, and Biondi [1977] which argues that creativity requires knowledge, imagination, and evaluation. The equation proposes that, in order to be creative in a particular situation, such as problem solving, first of all you need the appropriate knowledge (K). Then, you apply your imagination to the knowledge (I x K) in order to develop new combinations which can be classified either as ideas, as options, or as points of view. The final process is to apply your judgment in order to evaluate (E) which of these ideas should be discarded and which should be developed further. Nemeth [2004] proposes that creativity begins with a questioning attitude and the ability to "look outside the box." Recent research in psychology indicates that teams can stimulate creativity and problem solving by being open to dissenting voices and minority viewpoints that, in normal circumstances, would be rejected or ridiculed and that "cult-like" corporate cultures stifle creativity. Basadur's [2004] comparative study of creativity and employee suggestion schemes (ESS) between Japanese and U.S. companies found that in Japan "employee creativity is managed through deliberate structural means, not to effect direct economic outcomes, but to develop motivation, job satisfaction and teamwork." In contrast the schemes run in most U.S. organizations were motivated by money; the result was a failed model where only a minority got involved. Related ESS studies propose that employees should be encouraged to look for simple, focused solutions [Tushman and O'Reilly, 2004] to real problems [Drucker, 2003]. In the nature versus nurture debate on creativity, the work of Genrich Altshuller who developed TRIZ, a theory of inventive problem solving, is significant. TRIZ, an abbreviation of the Russian term *Teoriya Resheniya Izobreatatelskikh Zadatch* and pronounced "Treez," was developed to support engineers and scientists solving problems using knowledge from previous inventions. This knowledge was synthesized by Altshuller from an analysis of thousands of patents which exhibited a Pareto effect, where a large number of inventions were based on a small number of principles which he distilled into forty "inventive principles."

The importance of the motivation of technical professionals is of paramount importance, as evidence suggests that it is better to have a team with A-rated motivations and B-rated capabilities than vice-versa [Katz, 2004]. Herzberg's [1968] seminal work on motivation found that people are "motivated by interesting work, challenge, and increasing responsibility" (p. 87). Good management and working conditions will help to ensure that they do not become dissatisfied, but this will not meet their deep-seated need for growth and achievement. In order to manage creativity effectively, Leavy [2005] proposes that organizations place people and ideas at the heart of management philosophy where people are given room to grow, try things out, and learn from mistakes. In this environment managers are "symphony conductors" [Drucker, 1988], not army generals, and should implement the 7–3 formula; they should expect to make wrong decisions three times out of ten [Tushman and O'Reilly, 2004]. McAdam [2004] emphasizes the importance of knowledge creation (KC) and idea generation to activities such as the opportunity and design phases of product and service development. Furthermore, Afuah [1998] has identified five roles that individuals assume in the innovation process: idea generators, gatekeepers and boundary spanners, champions, sponsors, and project managers.

Teams have been described as the fundamental learning units in the modern organization [Pedler, Burgoyne, and Boydell, 1991] and are being used effectively in areas related to innovation such as product development, process-centered organizations, and project management [Cooper, 2001; Otto and Wood, 2001; Pugh, 1991; Ulrich and Eppinger, 2000]. Furthermore, quality function deployment (QFD) is an established tool to integrate the "voice of the customer" into the design process. In particular, the Kano model is used as a frontend to QFD and can be used effectively to map customer satisfaction against the degree of function implementation [Ulrich and Eppinger, 2012]. The way in which information and knowledge is disseminated is very important, especially in light of research quoted by Allen [2004], which shows an inverse relationship between contact of technologists with outside people and technical performance. The most effective model is where the organization has key people or "technological gatekeepers" on which most people rely for information. These gatekeepers are mediators with the outside world in terms of relevant literature, academics, and networks of practice. The introduction of new knowledge is more complex than commonly believed and is best carried out indirectly by making optimum use of knowledgeable staff and existing information systems. The role of empathy will be discussed later in the study, but here it is worth noting that Leonard [1998, p. 194] proposes emphatic design as the best method to import knowledge from the market place. Her definition:

> *Empathic design is the creation of product or service concepts based on a deep (empathic) understanding of unarticulated user needs.*

Presently, another important topic is the management of interpersonal processes in teams that communicate exclusively using information and communications technologies (ICT) with some research offering a model to match the ICT to the type of interpersonal interaction [Maruping and Agarwal, 2004].

According to Kumar and van Dissel, "interorganizational systems exist to support and implement cooperation and strategic alliances between two or more organizations" [Kumar and van Dissel, 1996, p. 281]. Furthermore, for quite some time, the dramatic growth of inter-organizational systems (IOS) have altered the way organizations conduct business and relate to each other [Premkumar and Ramamurthy, 1995]. The ever more important role of academia in supporting innovation in knowledge-based societies has led to the development of a number of models from national systems of innovation [Lundvall, 1995] to the more recent Triple-Helix model of university–industry–government relation [Etzkowitz and Leydesdorf, 2000]. With regard to the level of societal influences on innovation, Florida's 3-T model of technology, tolerance, and talent argues that the rise of the "creative class" is a key factor in the new economy [Kakko and Inkinen, 2004].

Recently, Chesbrough [2003] argues that in many industries the centralized approach to R&D which he terms "closed innovation" has become obsolete. This paradigm, he contends, must be replaced by "open innovation," which adopts external ideas and knowledge in conjunction with the internal process. A number of factors are influencing this change, such as the mobility of skilled people, the increasing presence of venture capital, emergent high-tech start-ups, and the significant role of university research. Companies such as Cisco and Intel have adopted the new paradigm in contrast to Xerox which has lost many innovators due to its closed systems. One of his principles is that "not all the smart people work for us," and he advocates that the smart people within an organization connect with the smart people outside. Embracing the ideas and inspiration in these external links, he contends, will actually multiply the advantage of internal efforts. However, connecting external innovation to internal innovation requires a new business model. The growing significance of the Open Innovation paradigm has prompted West, Vanhaverbeke, and Chesbrough [2006] to propose a research framework with the following classifications: individual, organizational, value network, industry/sector, and national institution (p. 288). In related work, Vanhaverbeke and Cloodt [2006] suggest that emerging forms of value networks must be examined at the level of different nested layers, which is close to the argument of this article. These diverse layers span the spectrum from the individual to firms–organizations, through Dyads, onto inter-organizational networks, and ultimately reaching to national/regional innovation systems. Von Hippel [2005] speaks about the democratization of innovation by which product– and services–users increasingly have the ability to innovate for themselves, with the resulting move from manufacturing-centric to user-centric innovation processes. It is interesting to note that the term *openness* has been recently explored by Almirall and Casadesus-Masanell [2010], and this would suggest that the terms *open* and *closed innovation* are not mere Boolean concepts. Another feature highlighted by Christensen, Yang, Verlinden, and King [2005] in their studies of the semiconductor industry is the problem of "performance overshoot," with the realization that Moore's Law is no longer the dominant paradigm for analyzing this sector. They predict from looking "through the lenses of the theories of innovation" that the future of the industry will be "very different than the past." Customers are less concerned about performance factors, such as clock speed, and more focused on new parameters, such as "convenience and customization." Furthermore, they contend, new "specialized non-integrated firms" will provide a serious threat to the incumbents; they have proposed "disruptive-innovation" and "value-migration" frameworks to assist the semiconductor industry to manage these transitions. This was as a result of previous studies by Christensen that had concluded that successful companies were good at managing evolutionary or sustaining innovation but "ran into trouble" when faced with revolutionary or disruptive innovation [Christensen and Overdorf, 2000]. There continues to be a lively debate in the literature on the nature of the firm and sources of competitive advantage [Klein, Mahoney, McGahan, and Pitelis, 2010; Pitelis and Teece, 2009]. According to some scholars, the area of management innovation is under-researched [Birkinshaw, Hamel, and Mol, 2008]. Thus it requires a strong theoretical basis in order to develop a comprehensive and fruitful research agenda; the objective of this article is to address this contention. Furthermore there has been a recent call for a more balanced view of innovation management that, for example, applies both bottom-up and top-down philosophies [Birkinshaw, Bouquet, and Barsoux, 2011].

Innovation Frameworks

Slappendel [1996] classified the innovation literature in terms of three theoretical perspectives based on the antecedent work of Pierce and Delbecq [1977]. These three theoretical approaches are the individualist perspective, the structuralist perspective, and the interactive process perspective, with the sequence reflecting their historical development. She argued that the increasing growth in innovation publications necessitates that both researchers and students “establish mental models of the domain” (p. 108), which is one of the main objectives of this study. Wolfe’s [1994] conclusion that the expanding innovation literature had made little contribution to the understanding of innovative behaviour in organisations, and his assessment was surely an indictment of the field. To redress this situation, he made a number of recommendations, including that more careful attention must be given to the “personal, organisational, technological and environmental contexts” of the innovation phenomenon being studied. Moreover, he identified three streams of research that should branch from the swelling river of innovation studies:

1. Diffusion of Innovation (DI): focused on the diffusion of an innovation over time and/or space
2. Organisational Innovativeness (OI): addressing the determinants of the innovativeness of organisation
3. Process Theory (PT): focused on the process of innovation within an organisation

Another support for an ecological framework is provided in the review by Gupta, Tesluk, and Taylor [2007] of innovation using multiple levels of analysis. In this work they conclude that there is an significant role for viewing innovation as a multilevel phenomenon.

As part of our work, we have identified a number of innovation process frameworks from the literature. These vary from Angle and Van de Ven’s [2000] “Innovation Journey,” which encompasses the broad spectrum of steps in the innovation process to others which focus on specific subsets of the innovation process. An example of the latter is Theresa Amabile’s framework for assessing the climate for creativity, which is known by the acronym KEYS [Amabile, Conti, Coon, Lazenby, and Herron, 1996]. Table 1 summarises both static and dynamic concepts extracted from our review of these innovation process frameworks. The column on the left provides some examples from the literature of static enablers of innovation. These incorporate such concepts as culture, climate, and technological capability. The column on the right provides examples of dynamic enablers. These include processes that organizations implement in order to develop an innovation from concept to implementation.

Table1: A Summary of Innovation Frameworks

Examples of static enablers	Examples of dynamic enablers
Amabile, 1996 • Support and information flow for new ideas • Individual ownership • Resources • Challenging work Basadur and Gelade, 2006 • Proactive acquisition of new knowledge • Sensing of trends, opportunities, and problems Dodgson, Gann, and Salter, 2005 • Availability of innovation technology (IvT)—think, play, do • Disruptive: doing things differently • Incremental: doing existing better Ekvall, 1996 • Freedom to make internal and external contacts • Trust and openness: no ridicule • Playfulness/humour • Conflict management • Tolerance of uncertainty • Idea Time • Debate: healthy clashing of views Afuah, 1998 • Patents, copyrights • Reputation • Profits • Technical, market, and architectural knowledge	Anagle and Van de Ven, 2000 • Shocks originating inside or outside the organization • Relationships • Infrastructure for external contacts (government, academy, trade associations) • Modification to local situation • Top management commitment • Process facilitators • Link old and new (graft onto existing organisation) • Termination • Attribution Chesbrough, 2003, and von Hippel, 2005 • Technology insourcing • User led • Licensing Cooper, 1994 • Gates • Reviews Flynn, Cooley, O’Sullivan, and Cormican, 2003 • Innovation funnel • Creativity process (sub) funnel • Quick wins Goffin and Mitchell, 2005 • Prioritisation (decision-making process) • Portfolio management • Cross-function teams • Quick prototyping

Information Systems Innovation

Swanson [1994] suggested a generic definition of a process innovation as “any new way of developing, implementing and maintaining IS.” Furthermore, he argued that current innovation theory had done little to explain IS innovation and where it stood within the general debate on organizational innovation. Consequently, he proposed a tri-core model of IS innovation with the innovation core sandwiched in a swiss-roll arrangement between the inner technical core and the outer administration core. An ensuing empirical testing of the model resulted in “cautious optimism” but suggested a need for further theoretical work to refine, elaborate, and extend the system [Grover, Fiedler, and Teng, 1997]. In a subsequent influential paper, Swanson and Ramiller [2004] start by defining IT innovation as the process by which “IT comes to be applied in novel ways” (p. 556) and conclude that the literature on bandwagon phenomena indicates that much supposedly innovative behavior is actually “me too” activities (p. 544). This leads them to propose the application of the concepts of *mindfulness* and *mindlessness* to IT innovation theory. Their call for an enlarging of the IS academic research to “investigate the cognitive processes of organizations” (p. 577) and to engage with the psychological as well as the organizational literature has relevance for the present study. Fichman [2004] places the concept of *mindfulness* with six other concepts (innovation configurations, social contagion, management fashion, technological destiny, quality of innovation, and performance impacts) and presents them as emerging perspectives that can take IT innovation research beyond its present *dominant paradigm,* which he believes is showing signs of exhaustion. He defines the *dominant paradigm*, derived from economic-rationalistic models, as positing that an organization with the greater quantity of *right stuff* will demonstrate a greater quantity of innovation. Recently, a comprehensive analysis of an extensive body of research, based on Fichman’s description of the *dominant paradigm,* resulted in a revised depiction of the model that differentiated between individual and organizational characteristics and prescribed the best predictors of IT adoption for each characteristic [Jeyaraj, Rottman, and Lacity, 2006]. This study concluded with a counter argument that the dominant IT paradigm was alive and well and continues to make significant progress.

Other scholars have taken a different approach when viewing information systems innovation. For example, the work of Tarafdar et al. [2005] examines how a firm’s information technology (IT) capabilities affect its ability to innovate. They explain that the IT capability of the firm has five dimensions: IT Infrastructure, IT Human Resources, IT-related Intangible Resources, IT Coordination, and IT governance. On a more general level, Pavitt [2005] argues that ICT can support innovation by reducing search and selection costs, and digitalization in general has resulted in systems of increasing complexity. Dodgson et al. [2005] propose that a range of new technologies, such as simulation and modeling tools, virtual reality, data mining, and rapid prototyping, have led to the *intensification of innovation*. They have used an umbrella term—*innovation technology* (IvT) to describe these new tools and methods. IvT, they argue, is being increasingly applied to innovation and, indeed, is dramatically changing the nature of the innovation process. Furthermore, they contend that IvT is having a significant influence on accomplishing creative tasks and on defining the ways in which knowledge is constructed, shared, and used. A recent and important ICT innovation is that of cloud computing launched by Internet giants such as Google and Amazon. The ubiquitous availability of computer networks facilitates provision of software as a service (SaaS) and other customer services. This has resulted in cloud computing being viewed as a fifth utility in the same way as water, electricity, gas, and telephone [Yang and Tate, 2012]. Meanwhile there has been increasing emphasis on delivering the optimum business value from IT investment as a source of innovation [Curley, 2006; Curley and Westerman, 2008]. A summary of IS specific innovation frameworks is shown in Table 2.

Table 2: IS/IT Specific Innovation Frameworks and Models

Author	Title	Description
Swanson, 1994	Tri-core Model	A tri-core model of IS innovation with the innovation core sandwiched in a swiss-roll arrangement between the inner technical core and the outer administration core.
Larsen and McGuire, 1998	IS Innovation Framework	Propose a “human activity system” view of IS innovation
Rose and Lyytinen, 2001	Quad Core (Tri-core add-on)	Proposed an extension of Swanson’s Tri-core model in order to account for observed radical changes in systems development and IS service due to Internet-induced innovations
Costello and Donnellan, 2007	Self-service Technology (SST) Tri-core add-on: Type IIId	Argued that the growing importance of self-service technology (SST) and self-service business has implications for Swanson’s model.
Baldwin and Curley, 2007	Managing Information Technology Innovation for Business Value	Outlines the business process approach to managing IT innovation at Intel

Avgerou and La Rovere [2003], have challenged the IS community to rethink "long-established disciplinary divisions and conceptual categories" (p. 206). Furthermore, they propose that IS studies must place the internal organizational processes within the wider socio-economic context.

Summary

The main point from this overview is that the study of information systems innovation is a complex, multidimensional phenomenon with dynamic interactive characteristics that invites a novel theoretical framework. Prior research does not adequately encompass the IS innovation spectrum which can be broadly described as follows: the person as the protagonist of the innovation phenomenon, operating in an ecological milieu of personal characteristics, entailing interpersonal relationships with immediate collaborators, exhibiting organizational features that support innovation, involving inter-organizational relations that enable IS innovations, embedded in a socio-economic context. In addition, existing theories do not sufficiently account for the dynamic relationship between person and environment that is contingent on the chronological flow of time and history. These concepts derived from the literature review will be used to map the layers of Figure 1 below (based on the incumbent ecological systems theory) to Figure 2, which will describe the ecological systems theory tailored for IS innovations.

We will address this by exploring an ecological framework to address this gap.

III. THEORETICAL DEVELOPMENT FOR INFORMATION SYSTEMS INNOVATION

Now we will return to our original question regarding the possibility of finding a theoretical framework that can accommodate the complex and multidimensional landscape of innovation and meet the criteria outlined at the end of the previous section. We will introduce ecological systems theory and argue that it provides a suitable framework for researchers to approach the topic of innovation and to examine its relationship with information systems.

Ecological Theories: An Overview

This section provides an overview of prominent ecological theories and provides a background to our argument that the framework of Urie Bronfenbrenner is most suitable to meet the present theoretical deficiencies in IS innovation research.

First we will define the term *ecology* for the purpose of this article. The ecological approach is normally taken as the interaction between an organism and its environment [d'Ydewalle, 2000]. However, a recent explanation of the term in the *Oxford Dictionary of English* [2006] defines *ecology* as a branch of biology that deals with the relations of organisms *to one another* and their physical surroundings. Therefore, we would like to build on this concept of the primacy of the relationship to others by offering the following definition: An ecological approach is the study of the relations between a person and his/her environment and to other collaborators within the environment. Ludwig von Bertalanffy was among the first scholars to propose a general systems theory in the 1940s [Bertalanffy, 1968]. The systems viewpoint developed in a variety of scientific and technological fields after this initial period. Bertalanffy (following Kuhn) presents *general systems theory* as a "novel paradigm in scientific thinking" (p. xvii) and proposes the following taxonomy: systems science, systems technology, and systems philosophy.

Kurt Lewin is regarded as the father of both social psychology and action research and is famous for his assertion that there is nothing as practical as a good theory. He believed that a fundamental goal of researchers is to put their theories into action in order to make the world a better place in which to live. Lewin trained in Europe during the early years of the twentieth century, and his academic formation was greatly influence by the Gestalt movement. Gestalt psychology proposes that an organized whole is perceived as more than the sum of its parts [ODE, 2006]. Borrowing an analogy from physics, he developed his psychological *field theory,* which evolved into his conception of *ecological psychology,* and this was further refined in the 1950s by his students Roger Barker and Herbert Wright [Jackson, 1998]. Lewin argued that scientific research requires a transition from the static classifications of what he termed an *Aristotelian* paradigm to a dynamic *Galilean* paradigm which studies the underlying theoretical processes which bring about the observed phenomenon [Estes, 2000].

J.J. Gibson was another influential theorist who introduced an ecological approach to the study of perception psychology arising from his work on pilot selection and the spatial challenges resulting from flying aircraft [d'Ydewalle, 2000]. Gibson [1986] proposed that the contemporary account of natural vision as a sequence of snapshots, *aperture vision*, be replaced by a dynamic perspective that took into account *ambient vision* and *ambulatory vision*. He developed his theory by considering an animal or person and their environment as an inseparable and mutual pair. Furthermore, the environment—ranging from atoms to galaxies—consists of structural units where smaller units are embedded in larger units in what he termed *nesting*. However, the most important levels from the point of view of perception is the ecological levels of the habitat which can be perceived by the sense organs, such as things we can "look at and feel, or smell and taste, and events we can listen to" (p. 9).

Organizational ecology is a prominent body of theory in sociological research that examines the interactions within and between populations of organizations. Its chief apologist Michael Hannan introduced the idea in the 1970s, building on evolutionary perspectives such as adaption and selection. Hannan developed his early work by engaging in the debates initiated by the influential Amos Hawley whose structural theory had launched a branch of research in the field of sociology [Britannica, 2008]. Hawley's emphasis on the critical role of technology—in what he termed *human ecology*—is of particular interest to this study. However, after thirty years of mainly empirical work in *organizational ecology,* there is a major concern with the fragmentation of research in the area. Hannan and his collaborators have recently sought to address this issue by undertaking a project of theoretical integration and unification that investigates the relationships among the distinct fragments [Hannan, Pólos, and Carroll, 2007]. Systems thinking has had a significant influence on the information systems debate, with Checkland [1993] proposing it as a particular way of trying to understand the world. His work with Holwell [1998] used systems thinking to view the "IS field as a whole" (p. 237). Furthermore he outlines the difference between the *hard systems* tradition and the *soft systems* tradition [Checkland and Scholes, 1992]. The former tackles real-world problems in which an objective is taken as given and where the system is engineered to achieve stated objects. The latter tackles real-world problems in which the know-to-be-desirable ends cannot be given.

Bronfenbrenner's Ecological Systems Theory

Urie Bronfenbrenner's development of Ecological Systems Theory [Bronfenbrenner, 1979] is regarded as having revolutionized studies in these areas by shattering barriers and building bridges among the social science disciplines. Previous to Bronfenbrenner's work, the study of human development was compartmentalized among psychology, sociology, anthropology, economics, and political science. However, through the concept of the ecology of human development, these disparate environments were integrated into a holistic conceptual framework of interdependent nested systems where human development was viewed as a continuum [Lang, 2005].

In his schema, development is regarded as a function of the person interacting with the environment, which includes the effects of both constancy and change (the time dimension) on personal characteristics throughout the lifespan [2005, p. 108]. Bronfenbrenner affirmed that a major motivation for his work was to provide both psychological and sociological depth to the theories of Kurt Lewin. From an IS viewpoint, it is significant that he claimed his theory differed from antecedent research models in that he analyzed the environment in *systems* terms. His theory is shown diagrammatically in Figure 1.

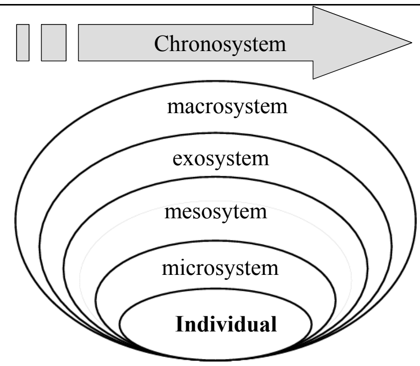

Figure 1. Ecological Systems Framework [Adapted from Cranefield and Yoong, 2007]

We will now describe each nested layer of the modified Bronfenbrenner model where the "patterned behavior" is determined by the following:

1. *Individual level:* Intrapersonal factors—characteristics such as knowledge, attitudes, behavior, self-concept, skills, etc. It also included the developmental history of the person.
2. *Microsystem:* interpersonal processes and primary groups—formal and informal social network and social support systems, including the family, work group, and friendship networks
3. *Mesosystem:* institutional factors—social institutions with organizational characteristics, with formal (and informal) rules and regulations for operation
4. *Exosystem:* community factors—relationships among organizations, institutions, and informal networks within defined boundaries
5. *Macrosystem:* public policy—local, state, and national laws and policies

6. *Chronosystem*: This was a later addition by Bronfenbrenner [2005] and was not taken into account by McLeroy et al. This concept "encompasses change or consistency over time not only in the characteristics of the person but also of the environment in which that person lives" [Marentette, 2007].

We have presented our argument that Bronfenbrenner's theory best matches the criteria developed earlier due to its comprehensive topology, its focus on relational interactions, and its synthesis of the concepts of ecology and systems. We will now present our adaptation of the model to address two main issues: incorporation of technology and emphasizing the importance of collaboration in the IS innovation process.

Elements of an Ecological Systems Theory for IS Innovation

Based on the foregoing analysis, we will now present our framework to analyze innovation based on Bronfenbrenner's theory. The structure is based on the implicit assumption that innovation originates from the human person, but is significantly influenced by interaction and interconnection with the five other layers. This contention also follows Bessant's [2003] conclusion that in dealing with the challenges of innovation; creating and reinforcing behavior patterns is the key management challenge.

We conceptualize our argument by modifying both Lewin's and Bronfenbrenner's equations in a format that explicitly includes the time dimension:

$$I_{(t)} = f\,(P_{(t)}\ E_{(t)})\ \ldots\ldots \qquad \text{(Eq 1)}$$

The next step is to propose a formula to capture the theoretical concept of an *EST for IS Innovation,* which builds on both Lewin and Bronfenbrenner, but specifically includes two extra dimensions: technology as an integral component of information systems and the interpersonal interconnections that are essential to the innovation process. The subject of technology is not specifically addressed in Bronfenbrenner's final work. However, it is alluded to via a quotation from the work of Lev Vygotsky who was influential on the development of ecological systems theory. As we pointed out earlier, theorists such as Hawley have stressed the importance of technology when seeking to understand human ecology. The relational aspect is captured in Bronfenbrenner description of the ecological *microsystem*. However, we propose that the concept is explicitly included in our formulation, given its importance for the IS innovation process which, either in the initiation stage or the implementation stage, cannot be carried out in total isolation. The formula (Equation 2) and EST for IS innovation diagram (Figure 2) are different representations of the same concept. The diagram provides the detail on the composition of the environment. The mapping of the layers in Figure 1 to the layers in Figure 2 are based on the literature review in the "Background" section of the paper above.

$$ISI_{(t)} = f\,(P_{(t)}\ R_{(t)}\ E_{(t)}\ T_{(t)})\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad \text{(Eq 2)}$$

Where ISI = information systems innovation

P = person

R = relational connections to collaborators within the innovation context

E = environment

T = technological capability

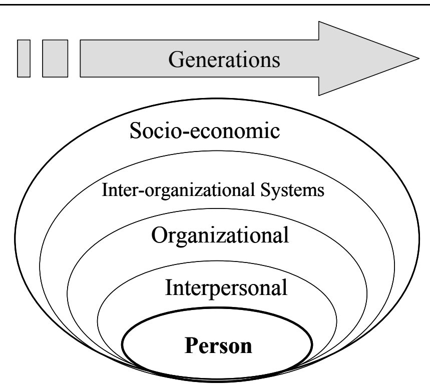

Figure 2. An Ecological Systems Framework for IS Innovation

The revised IS innovation framework is now described.

1. *Personal Dimension:* This layer includes the intrapersonal characteristics that assist or inhibit IS innovation. Development of ICT knowledge, skills, and competencies through education and training to support innovation, both in terms of creative invention and of implementation, are relevant here. Examples of IS innovations that apply to this layer include Personal Information Manager (PIM), Productivity Programs, word processing, spreadsheets, presentation software, Database software, Mind-mapping, TRIZ software, e-Learning, wikis, Internet, World Wide Web, semantic Web.
2. *Interpersonal:* Formally this dimension will include the ability of ICT to support and direct teams or work groups. Informally it will include social networks, communities of practice and personal contacts, both inside and outside the organization. The relationship between ICT and interpersonal attributes such as empathy will also be relevant in this layer. IS innovations would include email, chat, blog, C2C (consumer-to-consumer) technologies.
3. *Organizational:* The characteristics of the organization to which a person belongs will be significant for this layer. The effect ICT has on culture, climate, and the management of innovation and change will influence the person's tendency to innovate. IS innovations applicable at this level include videoconference, blog, wiki, tele-working, search engines, semantic Web.
4. *Inter-organizational Systems:* This layer will involve IS innovations enabling organizations to develop relationships that facilitate the flow of information from one organization to another. These automated information systems can reduce cost and allow data to flow seamlessly across organizational boundaries. Examples of IS innovations here include services that enable electronic data interchange (EDI), particularly in supply chains, to share data between computer systems.
5. *Socio-economic:* This dimension will include innovation policy of local, regional, state, and supra-national (for example, the European Union), National Systems of Innovation (NSI) [Lundvall, 1995], indicators of innovation [OECD, 2005], and important economic theories of innovation [Schumpeter, 1934]. Here IS innovations, such as e-government, C2G (citizen-to-government), and Patent Search Engines, can facilitate policy implementation.
6. *Chronological Generations:* Analogous to human development, "generations" can encompass a number of concepts. At a macro level it will take cognizance of the time dimension of the innovation environment which has been outlined, for example, in Rothwell's [1994] taxonomy of innovation processes. In the realm of information systems, Ward, Griffiths, and Whitmore [1990] developed a three-era model of IS to illustrate this concept.

IV. RESEARCH AGENDA

The purpose of a research agenda is to provide the impetus for the development of more detailed studies in a particular field. Based on our argument that an ecological-systems approach meets the deficits identified in our literature analysis, this section will provide suggestions using the following approach. First, we will suggest topics as they relate directly to the layers of the ecological system. Then we will outline a number of high-level new directions which could have a considerable impact on our field but require the courage to explore new territories. Next we suggest specific research themes from the work of Bronfenbrenner and his collaborators. Finally, we put forward the case for implementing novel approaches to study designs based on the methodologies of ecological systems researchers.

Applying the Layers of the EST for IS Framework

This section will look at the general applicability of the adapted ecological systems theory at each of the ecological layers and will explore limitations of the framework, i.e., where it does and doesn't hold.

Investigation of the Personal Layer

This is probably the richest layer for the application of ecological systems theory. Studies of the application of information systems at this level will allow consideration of the person in relation to the nested ecological layers of the framework. Investigating this layer will require more connections with the psychological literature (see Swanson and Ramiller, 2005). Such engagement with the human person will also require wrestling with philosophical questions, and this could challenge the present coyness in the discipline for exploring such topics [Weber, 2003a, 2003b, 2004].

Investigation of the Microsystem

This layer was labeled the "interpersonal" in the adapted framework of Figure 2). It will involve exploration of such soft topics as empathy and the role of IS in teamwork [Ciborra, 2002; Leonard and Rayport, 1997; Maruping and Agarwal, 2004; Stein, 1989]. This area is ripe for investigation but is somewhat limited by the lack of theoretical frameworks available. One particular field that seems necessary to explore is the role of interpersonal relationships in automated information systems employing artificial intelligence (e.g., speech-enabled self-service) and the use of avatars in relational exchanges such as ecommerce.

Investigation of the Mesosystem

The mesosystem in the topology of Figure 2 refers to the organizational layer which, as was pointed out, is regarded as the most researched area of information systems [Crowston and Myers, 2004]. However, the framework provides a wider context for the exploring of organizational issues than is currently employed. It will challenge researchers to consider the implications of the other layers for the organizational context.

Investigation of the Exosystem

The area of the exosystem was referred to as *inter-organizational systems,* an area of established interest to the IS discipline in an era of rapid growth fuelled by the Internet and mobile technologies. A related phenomenon is that of transactions been carried out using automated agents [Pujari, 2004], together with the recent research area of autonomic computing. Investigations are limited currently by the lack of research and theoretical frameworks to explore these areas. It is considered that the EST will provide an impetus for such exploration and examine the relationship to other areas of the ecological system.

Investigation of the Chronosystem

This is perhaps the least researched and most nebulous layer of the ecological system, but the discipline has been challenged recently to explore such concepts as history and time [Markus, 2000]. The adapted EST will, it is argued, provide a framework and impetus to explore this area.

New Research Directions—General

Development of IS innovation Theory—Teleological Explanation: Gregor [2006] in her important essay on the structural nature of theory proposes the following five types: analysis, explanation, prediction, explanation and prediction (EP), design and action. However, we argue that EST invites an additional type: that of *teleological explanation*. Teleology is a branch of philosophy that seeks to explain phenomena in terms of the *purpose they serve* rather than by the more conventional method of *postulated causes* [ODE, 2006]. Therefore, *teleological explanation* endeavors to account for phenomena with regard to their contribution to obtaining the most favorable states, the realization of certain goals, or the systems to which they belong. The origin of the concept is sometimes traced to the story told by Plato, in *Phaedo*, of the quest by Socrates to understand phenomena in terms of *what is best* [Bogen, 2005]. Consequently, we invite researchers to explore information systems innovation from a contrasting lens than conventional theory and open the discussion of an IS theoretical *teleology.* Lerner states that Bronfenbrenner moved human development science from describing *what is* to creating a vision of *what could be*. Perhaps these conversations require what Lester and Piore [2004] call *interpretive spaces* where IS innovation is viewed in terms of developing new language communities rather than the conventional approach of rational decision-making. Our suggestion is to transpose this thinking to our discipline.

The Philosophical Underpinning of an EST for IS innovation: Markus and Saunders [2007, p. iv], in their call for more concepts and theories to stimulate IS research, have specifically requested essays that explore the philosophical foundations on which IS theory and research is built. We share this conviction that good theory must be constructed on solid philosophical structures. This viewpoint is also supported by Gregor. She drew from, among others, the philosophical wellsprings of the interpretivist tradition, which is very relevant to our study [Gregor, 2006, p. 614], as the theory of Bronfenbrenner is steeped in the antecedent work of Lewin who examined the world through a phenomenological lens. Weber stresses that the status characteristics of a good theory depends on authors being “true to the philosophical position they adopt in relation to the theory” [Weber, 2003b, p. vi]. Quinton [2005] divides the world of philosophy—like Gaul—into three parts: theory of existence (metaphysics), theory of knowledge (epistemology of justification of belief), and theory of value (ethics). We propose that important work is required to develop a philosophical structure to support the EST for IS innovation theoretical framework and suggest that Quinton’s taxonomy is a suitable way to approach this. However, we follow Gregor’s [2006, p. 634] candid declaration that there is great difficulty in “presenting very complex philosophical issues in a limited space,” calling for separate focused study on this theme.

An Ecological Ontogeny for IS Innovation: We use the term *ontogeny* here to mean the study of the development of a person in the domain of IS innovation from the earliest stage of involvement in the process to attaining higher levels of maturity. According to Bronfenbrenner’s view, the developing person is not just a tabula rasa being formed by the environment, but that person must be viewed as a “growing dynamic entity that progressively moves into and restructures the milieu in which it resides” [1979, p. 21]. Furthermore, from the beginning of his work, Bronfenbrenner had insisted that the development of individuals cannot be separated from the social networks where they are located [Cairns and Cairns, 2005].

Role of Technology in Human Development: The translation of a theory from the human development literature we believe uncovers an important, but hitherto undeveloped, area in our discipline: the implications that technology and in particular ICT have for human development at different stages. Vygotsky had planned to "trace the changes in thought processes that are brought about by technological change," but he did not live to see the completion of this work [Bronfenbrenner, 2005, p. 124]. IS has had increasing influence on human life in ways that Vygotsky could scarcely have imagined, and we believe it is incumbent on the academic community to provide honest assessments of the resulting influences on cognition, behavior, and values. A framework to explore these questions is offered in our next suggestion.

A Relational Taxonomy of IS: In this section we will build on the discussion of the relational concept which is central both to EST theory and important definitions of innovation, such as that of Van de Ven's, which encorporates "people who over time engage in transactions with others." From the beginning of his work, Bronfenbrenner [1979] had argued that, in contrast to traditional experimental design, in *ecological research the principle main effects are likely to be interactions* (p. 38). Furthermore, we propose that Brentano's concept of intentionality and his "tripartite structure of mental life" can provide a fruitful basis to develop a relational taxonomy of information systems [Moran, 2000, p. 45]. We believe that this is important work given the recent interest in the IS literature on subjects such as virtual reality, automated agents, and autonomic computing. The following points are suggestions for a possible taxonomy to examine important developments that have shaped and are shaping the IS world from a relational perspective. Initially, person-to-person communication took the form of synchronous voice telecommunication and the later introduction of asynchronous data transfer. The current development of the hardware and software has resulted in asynchronous communication such as email and texting becoming *de facto* real-time communication, which has blurred the synchronous/asynchronous relational divide. This phenomenon invites the examination of a concept that we term the *pseudo*-synchronous. The person-to-machine interaction driven by self-service technology has altered the relational landscape. Interfaces now include the use of artificial intelligence, such as speech technologies with natural language understanding (NLU) capabilities. The machine-to-machine communicational relationship has evolved from traditional EDI into the increasing necessity of building intelligence into the network, such as the emerging area of autonomic computing. Finally, we propose that the area of virtual interaction by means of avatars invites a relational examination.

Research Themes

Having provided suggestions for high-level research direction, we will now present specific themes arising from Bronfenbrenner's framework.

Plasticity: Lerner defines *plasticity* as the potential for systematic change that is associated with the interaction between the individual and environment. We suggest that the optimistic idea that true human development can be enabled by dedicated policies and programs can be translated into the field of IS innovation.

Reciprocity: Bronfenbrenner argued that the relationship between a person and the environment is bi-directional and characterized by the concept of *reciprocity,* which could be a useful construct in the examination of the interaction between a person and innovation in the IS context.

Phenotypes: Here we suggest the study of IS innovation *phenotype*: the *observable characteristic* of a person (in this case innovative behavior) in relation to its ICT environment.

Settings: Bronfenbrenner defined a setting as the place where people are engaged in *face-to-face* communication and proposed that the factors of *activity, role,* and *interpersonal relations* were the main elements of the immediate setting. This, we believe, could be a useful taxonomy to investigate the immediate context in terms of IS innovation.

The Semiotic System: Bronfenbrenner redefined the microsystem in his later work to include the symbolic feature of the immediate environment. Lerner [2005] points out that the inclusion of interactions with the semiotic system—the domain of symbols and language—is very significant. This could build on recent IS work by Goldkuhl [2012] in the area of signs, symbols, and actions.

Study Designs

Ecological Experiments: Bronfenbrenner [1979] proposed that the fundamental purpose of the ecological experiment was not to test n hypothesis but "*discovery*—the identification of those system properties and processes that affect and are affected by the behavior and development of the human being" (p. 37). The main function of the experiment in this situation was for *heuristic* purposes. Bronfenbrenner argued that an "experiment of nature" provides a ready-made opportunity to study a phenomenon especially where change is involved. IS environments, moreover, are very complex and include the added dimensions of the person adapting to and altering the setting itself. Consequently, the utilization of simplistic and single dimensional research models has little chance of capturing or shedding light on the problem being studied. Bronfenbrenner argued for the experimental counter-intuitive approach of “controlling-in,” rather than “controlling-out,” as many “theoretical relevant ecological contrasts as possible” (p. 38) in order to assess the generalization of the phenomenon beyond the particular ecological setting being studied.

Implication for Researchers

Dyads: Bronfenbrenner’s *dyadic* theory implies that the research is not a static observer but is also a developing person during the research process. Enid Mumford briefly alludes to this when outlining the competence that an action researcher needs to acquire in their role. She implies that being involved in action research will result, in turn, in the development of these competencies [Mumford, 2001]. This concept, we believe, suggests the intriguing area of investigating the *hermeneutic circle* of the researcher during the research process.

Validity: The concept of *validity*—“the extent to which a research procedure measures what it is supposed to measure” [1979, p. 29]—is very important in research, and Bronfenbrenner deals with the term in a number of dimensions: ecological, phenomenological, developmental, and transcontextual. Further work needs to be done on the implication of Bronfenbrenner’s definition of *ecological validity,* which refers to “the extent to which the environment experienced by the subjects in a scientific investigation has the properties it is supposed or assumed to have by the investigator” [1979, p. 29]. *Phenomenological validity* refers to the correspondence between the subject’s and the investigator’s view of the research situation; *developmental validity* refers to the demonstration that human development has occurred; *transcontextual validity* involves finding developmental principles “that can be shown to hold good across physical and cultural setting, time or cohort” [1979, p. 128].

*Rigor versus Relevance***:** The subject of rigor and relevance continues to cause much debate and no little angst in the IS discipline. However, it should be of some comfort that Bronfenbrenner was deeply engaged in the same debate in the psychology and human development field. It is interesting to note his criticism of empirical psychology as having adopted research approaches mainly from the world of physics rather than the natural sciences. His main concern with this viewpoint is that it presupposes that physical and psychological objects and environments are the same. However, he states that, unlike physical objects, human beings have “perceptions, feelings, expectations and intentions with respect to the situations in which they are located” [Bronfenbrenner, 1979, p. 127]. The solution offered by Bronfenbrenner to this perennial debate was to build context into the research model from both the viewpoint of theory and empirical work and through both expanding and converging the naturalistic and experimental research approaches within his ecological systems theory.

Implications for Practitioners

The theoretical framework proposed in this study is readily accessible to practitioners who can map out the organizational ecology in order to gain understanding before embarking on projects either internally or externally (such as outsourcing). It could be particularly advantageous to map out a holistic framework for research and development (R&D) groups and product/service portfolio managers. The ecological approach could provide guidance for IS developers operating in an increasingly complex ecological environment, especially in the complexity of operating with many outsourced subsystems.

V. CONCLUSIONS

According to Damanpour, Walker, and Avellaneda [2009], innovation is a primary source of economic growth, industrial change, and competitive advantage. Brynjolfsson and Saunders [2009, p. ix] conclude that the fundamentals of the world economy indicate that there will be a continuation of innovation “through the booms and busts of the financial markets and of business investments. Furthermore, the importance, nature, and philosophical underpinning of theory continue to be the subject of lively debate in the information systems literature [Gregor, 2006; Markus and Saunders, 2007; Weber, 2003b]. Innovation is a multifaceted phenomenon that is increasingly seen to be crucial to an organization’s success and even survival. However, after many years of investigation, the contribution to theory is still being questioned and found wanting by many researchers in the area. The topic is relatively unexplored in the information systems field, and there has been calls for a more radical approach to stimulate research and debate among the IS community. The goal of this article is to apply some theoretical glue [Whetten, 1989] to the “fragmented corpus” of IS innovation studies [Adams, Bessant, and Phelps, 2006] in order to lay the groundwork for a research impetus in this increasingly important area. A review of the literature suggests an ecological approach to the study of information systems innovation. Ecological approaches consider both the organism and its environment, as well as the dynamic interactions between the two. An adaptation of ecological systems theory is proposed in order to address the gaps identified in the review of the literature. The tailored theory, which is the basic argument of this article, includes the dimension of technology and a greater emphasis on the relational aspect of the ecology. Furthermore, it is argued that the new theoretical framework can provide an impetus for research in the area. The literature is unanimous in claiming that the topic of innovation is very complex. Ecological systems theory has the breath, depth, and a proven track record to accommodate complexity.

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Editor's Note: The following reference list contains hyperlinks to World Wide Web pages. Readers who have the ability to access the Web directly from their word processor, or are reading the article on the Web, can gain direct access to these linked references. Readers are warned, however, that:

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Communications of the Association for Information Systems

ISSN: 1529-3181