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Perspectives on Emergence in Information Systems Research

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Perspectives on Emergence in Information Systems Research

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Abstract:

In this research essay we contend that “emergence,” or the formation of complex wholes from parts, is a fundamental concept for comprehending the dynamic relationships between people, technology, and organizations during the ongoing cycles of design, appropriation, and use of information systems. Past research on emergent phenomena use the concept with varying degrees of attention to the structural and functional changes that have occurred to components in the emergent whole or to the implications of the processes by which emergence occurs. Refining our perspectives of emergence will guide researchers in clarifying how the socio-technical whole is greater than the constituent parts and how the whole comes into existence over time. In this article, we define three forms of emergence and provide both research exemplars and a framework for categorizing emergent phenomena to better articulate and refine how we understand emergent phenomena in Information Systems.

Keywords: emergence; qualitative novelty; combinatorial; associative; process

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I. INTRODUCTION

“Emergence” is broadly defined as the “coming into being of qualitative novelty” [Bunge, 2004, p. 3] as wholes are formed from parts. Emergence phenomena are characteristic of complex systems, organizational innovation, and self-organization in disciplines ranging from biology to physics and organizational studies to Information Systems (IS). Emergent phenomena are of increasing interest to IS researchers as they observe the novel phenomena that occur when technologies, information, organizations, and human goal-seeking behavior intersect. Although widely referred to in IS literature, emergence is often poorly specified by researchers, leading to ambiguity and confusion regarding the properties and processes through which novelty comes to be. The ambiguous meanings of emergence in IS literature result in a lack of clarity regarding the relationships among parts in an emergent whole, selection of suitable research approaches, and the processes of emergence.

Emergence is a central phenomenon in multiple research perspectives including complexity theory [Benbya and McKelvey, 2006], socio-technical research [Lin and Cornford, 2000], general process theory [Seibt, 2009], organization studies [Lichtenstein, 2008; Truex, Baskerville and Klein, 1999], and socio-material perspectives [Barad, 2007; Orlikowski and Scott, 2008]. The multiple conceptualizations of emergence combined with the desire to identify and account for qualitative novelty frequently leads researchers to refer to phenomenon, processes, and technologies in IS research as emergent. However, emergence often has quite different referents: structural differences, an inability to predict outcomes, completely new properties, or innovative processes. The lack of specificity in researchers’ categorization of phenomena as emergent diminishes our ability to provide a clear account of related phenomena. Many system development activities, patterns of system appropriation and use, and properties of organizational systems and groups are described as emergent; however, researchers do not specify the structural and functional implication and the processes of emergence. Confounding the different forms of emergence contributes to a “black-boxing” of complex phenomena. For example, claims that organizations are continuously emerging and “in a state of continual process, never arriving but always in transition” [Truex et al., 1999, p. 117] implies a state of constant change. But the emphasis on constant newness obscures stable and continuing structures or relationships underpinning organizational behavior. As IS researchers seek to engage emergence phenomena, we must differentiate between the multiple forms of emergence to better comprehend the phenomena and understand the limitations of prediction and determination of outcomes. Knowing the implications of emergence will also enable us to select appropriate research methods and to evaluate claims of emergent phenomena in IS. In this article, we develop a framework and terminology for emergence that will clarify the way in which research can be structured and communicated.

Our focus is on the phenomena that emergence entails. This article is intended to refine the discourse for how IS researchers articulate systems in the world that capture broad socio-technical constructions that may evolve over time. In this effort, we develop a framework that represents three forms of emergence that inform IS research beyond common language usage as: (1) wholes as described by the emergent properties of their parts, (2) wholes whose emergent properties are distinct from any of their parts, and (3) emergence as a set of processes, not as a singular entity or object. Our research essay then proceeds to analyze published examples of each form of emergence. We provide an overview of each of the forms and describe the rhetorical and methodological framing to illuminate the key characteristics of each. We use these definitions and descriptions to create a framework that will aid researchers in explicitly and consistently articulating emergent phenomena.

II. FORMS OF EMERGENCE

Emergence is a central phenomenon in many disciplines concerned with complex systems, self-organization, and the origins of novel entities, properties, or processes. The notion of a “whole before the parts” can be traced back to Aristotle, while the more modern conception of a dynamic construct arising over time is credited to philosopher G. H. Lewes [Goldstein, 1999]. Emergence is broadly concerned with behaviors in dynamic systems that arise from interactions of the parts but cannot be predicted from the properties of those parts [Casti, 1997]. Emergence is a central concept in physics, evolutionary biology, complex adaptive systems, and complexity theory [for a review, see Bunge, 2004; Goldstein, 1999; Juarrero and Rubino, 2008].

Emergence is based on an assumption that “every object is either simple or complex—in some respect or at some level” [Bunge, 2004, p. 9]. Words are composed of lexical units, theories are composed of parts [Weber, 2012], atoms and molecules are composed of elementary particles, cells are composed of molecules that, in turn, form

organs and people. Emergence accepts that “micro phenomena are embedded in macro contexts and that macro phenomena often emerge through the interaction and dynamics of lower-level elements” [Kozlowski and Klein, 2000, p. 7]. Complex systems (high level) are a result of the interactions of the components (low level) and of the organizing principles of these components—changing the composition of a system or changing the structure of the components changes the properties of the whole.

Different forms of emergence share the characteristic of something being perceived as qualitatively new. A common use of emergence is to indicate that an idea, entity, or process has come into the researcher’s view or awareness. This usage carries anthropocentric connotations and often takes a declarative form such as, “the sun emerged from the clouds” in which the emergent entity or property existed but was physically hidden or obscured. While this is a clear and definable form of emergence, it is not the focus of our research essay.¹ This form does not provide refined enough considerations from which different forms of emergence can be identified precisely.

Emergence in IS research can be understood as the arising of novel and coherent structures or behaviors by which high level outcomes result from interactions at lower levels [Bunge, 2004; Goldstein, 1999]. At the basic level, Bunge [2004] identifies structural differences in the formation of wholes from parts: modular structures, in which parts are aggregated or associated together, and integral structures, in which elementary parts become combined or fused to form something novel. Although both forms exhibit novelty (i.e., a lever is an aggregate of a fulcrum and a beam and has properties that neither has alone), the components in an aggregate are not changed by the process. For example, the modular structures of an IT architecture can be analyzed by comprehending the component parts. The overall network may be emergent and novel in its first instantiation, but this emergence does not imply that the properties of the components have been changed. In contrast, integral structures have novel properties based on synergistic interactions of the components [Bunge, 2004; Corning, 2002] that alter the components themselves. Thus, properties of molecules are different from the component atoms, and the properties of the atoms are changed by the whole. Integral emergent structures may also exhibit path dependency, suggesting that the order or timing in which components are added alters the properties of the whole and, in socio-technical contexts, results in persistent change. Large-scale infrastructure development [Lee, Dourish and Mark, 2006], open source software communities [Kelty, 2009], and boundary-spanning practice competencies [Levina and Vaast, 2005] are examples of an integral form of emergence.

The distinction between modular and integral forms of emergence highlights structural differences between the emergence of entities or artifacts but does not account for the processes that result in these forms, nor does emergence refer only to novel objects. In IS, the intentionality and agency of human actors in socio-technical systems [Boudreau and Robey, 2005], changing environments, changing tasks, and new technology enable emergent processes, practices, and knowledge. For example, the processes by which communities or boundary-spanning practices emerge are of great consequence as they demonstrate the influence of temporal ordering and may require different methodological approaches. These structural distinctions serve to introduce the conceptions of emergence upon which we will focus for informing IS research: associative (weak) and combinatorial (strong) emergence and emergence as process.

Associative and Combinatorial Emergence

Emergence indicates that the properties of wholes are different from, but arise from the interactions of, the properties of the constituent parts. To say a phenomenon emerged is to claim that an entity or the properties of an entity came about from the interaction of lower level parts. From this formulation, two forms of emergence are identified: (1) associative emergence, in which constituent parts are aggregated and the properties of the whole can be predicted by attending to the properties of the constituent parts, and (2) combinatorial emergence, in which the constituent parts are combined or fused such that the properties of the whole cannot be predicted from the properties of the parts.

Although some literature refers to associative emergence as a weak form, we emphasize the modular structural aspects of the emergent whole rather than the strength of the effect. In associative emergence, “bottom-up processes describe the manner in which lower-level properties emerge to form collective phenomena” [Kozlowski and Klein, 2000]. As the component parts are not altered, researchers can predict the properties of the whole by understanding the properties of the parts. This modular structure results in these phenomena being amenable to reductionist research approaches. For example, organizational constructs like organizational memory “do not just

¹ Perceptual emergence is a simple and internal form of emergence. We do not explicate its characteristics in this article because its characteristics do not represent a collection of parts to a whole or a change in properties over time. Perceptual emergence is quite simply observing a steady-state object that was formerly hidden.

'exist' but emerge from processes and practices at lower levels of the organization" [Burton-Jones, 2005, p. 73] that can be measured by aggregating findings at the individual level.

Combinatorial emergence, on the other hand, is a distinct and more complex form of emergence in which the properties of the parts undergo transformations while combining to produce novel emergent properties [Bunge, 2004; Kim, 2008; Kozlowski and Klein, 2000]. For example, the properties of water cannot be predicted or explained by understanding the atomic properties of hydrogen and oxygen. In IS, the formation of online communities, either ephemeral or persistent, is not reducible to the properties of the individuals or the technologies that compose the information system. A combinatorial emergence property "cannot be represented in the initial and boundary conditions. In short, a feature emerges when the underlying system puts some effort into its creation" [Crutchfield, 1994, p. 1]. Emergence can take the form of functional complementarities or synergies, where parts together create a more adaptive or more stable whole; or where parts engage in a division of labor [Corning, 2002]. Combinatorial emergence calls into question the predictive capability of reductionism because a whole cannot be reduced to the properties of the parts. Examples of properties that may emerge include resilience, capacity, and adaptability. Combinatorial emergence is a more complex form of emergence because the "behavior of large and complex aggregates of elementary particles, it turns out, is not to be understood in terms of a simple extrapolation of the properties of a few particles. Instead, at each level of complexity entirely new properties appear" [Anderson, 1972, p. 393]. For example, boundary-spanning practices [Levina and Vaast, 2005] emerge when actors accumulate and engage resources in ways not consistent with current local practice. Instead, new practices emerge that transcend the former boundary conditions. The IS discipline itself represents combinatorial emergence as it originated "from the inability and unwillingness of existing academic disciplines to address the new phenomena surrounding the widening distribution and application of general purpose computers" [Hassan and Hovorka, 2011, p. 8].

Emergence as Process

The term "emergent" is frequently used to describe entities, or used as a property of an artifact. In the previous discussion, we distinguished emergent wholes as aggregations of parts, such that understanding the components leads to comprehension of the whole from fusions of parts that create something novel and irreducible. But researching emergence often requires that the interactions, not just the end-state properties of emergence, be investigated. In selecting research methods, researchers often assume that independent variables have an instantaneous effect on dependent variables; however, "this may not be the case; especially in collectives, [where] the relationship between predictor and outcome variables may take time (e.g., days, months or years) to emerge" [Burton-Jones, 2005, p. 671]. Therefore, time is fundamental to observing emergent processes. Emergence, when conceived of as a process, means that while component interactions may change over time, it does not require the addition of new components, but may involve learning, increased competence, bricolage, or changes in response.

This view of emergence can be used as a lens to understand seemingly contradictory findings. For example, the Theory of Task-Technology Fit (TTF) holds that the fit of technology to the task is a strong indicator of performance [Goodhue and Thompson, 1995; Zigurs, Buckland, Connolly and Wilson, 1999]. Other research, however, suggested that TTF is a good predictor of team performance for repetitive, structured tasks but, "depending on the duration and expected repetition of the tasks to be performed, system selection criteria solely on the basis of fit may not be the best method for longer term performance, but consideration of the *potential manner in which the task can be performed (future appropriations) is important*" [emphasis added; Fuller and Dennis, 2009, p. 14]. This latter research indicates that the processes of technology appropriation and task performance do not remain constant but are themselves emergent as the team interacts over time.

Emergence as process shifts the focus away from the properties of systems that are relatively static, to the improvisations, negotiations, ongoing, and even accidental changes that emerge. Emergence as process can highlight the specific paths underlying a phenomenon (e.g., appropriation, trust), the sequence and intensity of interactions of components, and the timing of events that form collective phenomena. Emergence as process may also occur as people reflect upon, restructure, and appropriate new technologies, new technology-enabled processes, and new assemblages of people, information, and technology [Germonprez, Hovorka and Gal, 2011]. Knowing emergence as process may prove useful for understanding the unfolding of systems in practice, the impact of systems on daily lives, and the evaluation and evolution of IS design in organizational contexts.

III. EXEMPLARS

A variety of IS phenomena are described as emergent in the IS literature. To increase our understanding of the types of emergence, we provide select exemplars of the refined types presented here: associative, combinatorial, and process. These are not intended as an exhaustive review but rather an opportunity to provide a more detailed description of each conceptualization of emergence by describing its rhetorical framing, the method used in the research, and a summary of how emergence is viewed in the research.

Exemplars: Associative Emergence

High-level phenomena emerge from the association or aggregation of lower-level phenomena, making associative emergence of fundamental interest. IS researchers are frequently interested in phenomena that span individual, group, organizational, and societal levels. To perform research on group or organizational-level phenomena requires the development of theory that accounts for the emergence of collective phenomena. Examples of associative emergence can be found in both quantitative and qualitative research.

Table 1: Examples of Associative Emergence

Example reference	Research focus
"Towards a Deeper Understanding of System Usage in Organizations: A Multilevel Perspective" [Burton-Jones and Gallivan, 2007]	Organizational system usage is a collective phenomenon measurable with structural and functional configurations of individual use.
"A Research Agenda for Studying Open Source [I and II]: A Multi-Level Framework" [Niederman et al., 2006a, 2006b]	Open Source Software development and implementation spans multiple levels of stakeholders and can be addressed through integration of multiple theoretical perspectives.
"The Role of Information Technology in the Organization: A Review, Model and Assessment" [Dewett and Jones, 2001]	Information technology is associated with people and knowledge and moderates between organizational characteristics and outcomes of efficiency and innovation.

A detailed examination of one example from Table 1 [Burton-Jones and Gallivan 2007] shows that organizational system use can represent associative emergence. In explicating the methodological issues in the development of a construct of collective use, this research details prior work on aggregating measures of individual system use [Kozlowski and Klein, 2000; Morgeson and Hofmann, 1999]. Although Burton-Jones and Gallivan [2007] use emergence in different ways to describe different phenomenon, including the emergence of communities, emergent behavioral and cognitive patterns in a group, and the emergence and change of the specific construct of system usage, the focus of their article is on "system usage as the aggregation of individual behaviors" [Burton-Jones and Gallivan, 2007, p. 659]. The authors provide guidance for the identification of collective usage and stress structural and functional configuration in the development of collective constructs. Associative constructs may "originate in the attributes of individuals and emerge at the collective level in the form of homogeneity among the collective's members" (p. 666) (e.g., similar intensity and frequency of use) or may "originate in the attributes of individual members and emerge at the collective level in the form of a distinct pattern among members of the collective" (p. 666) that is stable. This specific treatment of emergence considers associations as "patterns of action and interaction where two or more [entities] are mutually dependent on each other" [Karsten, 2003, p. 408] and suggests developing a collective construct by aggregating measures.

The methodological considerations described in Burton-Jones and Gallivan [2007] provide insight for research into other emergent wholes that are constituted by associative processes. In this case, group-level use is an associative emergence for which "the simplest way to conceive of use is as a pattern of individual usage across members" (p. 668). The authors further suggest that the individual measurements may be aggregated into a collective understanding using statistical methods including cluster analysis, min/max score, distribution of scores, and weighted calculation of scores. These insights emphasize the development of aggregate constructs through careful and consistent definition of the form of aggregation (system, user, or task) and the statistics for aggregating individual measures. This attention to method provides clarity in both the definition of the construct and the coherence of the theory into which the construct is embedded [Weber, 2012].

Exemplars: Combinatorial Emergence

Combinatorial emergence suggests that complex phenomena cannot always be understood and predicted through post hoc reduction to the lower-level components. Proponents of combinatorial emergence argue that knowing the component parts does not allow for predictable creation of a whole. For instance, a reductionist accounting of the composition, functions, and structures of a living human is not sufficient to create one. Nor is knowledge of factors that contribute to innovation, or to social communities of boundary-spanning research, sufficient to ensure successful future initiatives in those areas. In Table 2 we provide examples of combinatorial emergence.

As an extended example, we highlight a case in which organizational transformation "is grounded in the ongoing practices of organizational actors, and emerges out of their (tacit and not so tacit) accommodation to and experiments with everyday contingencies, breakdowns, exceptions, opportunities, and unintended consequences" [Orlikowski, 1996, p. 65]. This focus on the sources of organizational change following the introduction of new

Table 2: Examples of Combinatorial Emergence

Example reference	Research focus
"Improvising Organizational Transformation Over Time: A Situated Change Perspective" [Orlikowski, 1996]	New patterns of organizational practice occur in the absence of explicit planning and cannot be anticipated.
"The Human Infrastructure of Cyberinfrastructure" [Lee, Dourish, and Mark, 2006]	Infrastructures, both technological and human, emerge from a combination of old and new procedures and show diverse views of organizational structures, networks, and distributed teams.
"Collaborative Adhocracies and Mix-and-Match Technologies in Emergency Management" [Mendonca, Jefferson and Harrald, 2007]	Improvisation results from the emergent interoperability of information communication technologies in emergency response situations.

information technology observes combinatorial emergence "realized through ongoing variations which emerge frequently, even imperceptibly, in the slippages and improvisation of everyday activity" (p. 89). Thus, low level, everyday activities that "are repeated, shared, amplified and sustained can, over time, produce perceptible and striking organizational change" (p. 89).

Methodological consideration in Orlikowski [1996] emphasizes a longitudinal outlook and draws attention to the level of everyday practice rather than managerial orchestration of change or technological inevitability. Combinatorial emergence is the result of the interleaving of deliberative changes in practice with improvised changes that, in combination, result in significant organizational change. Although the combination of parts can be understood after the fact, the specific temporal ordering of changes is not amenable to a reductionist approach except in very general terms. The specific trajectory of situated change was not predictable by knowing the characteristics of the technology, the actors, or the original work practices.

Exemplars: Emergence as Process

Emergence as process is particular to systems involving intentional action. We stress the intentional nature of these interactions to differentiate them from the collective behaviors resulting from the unconscious or habitual nature of individual actions [Burton-Jones, 2005]. Emergence as process accounts for unanticipated behaviors or practices that come to be because of specific interactions of the participants. These interactions have been referred to as the "double interact" where the behavior of individual A evokes a response from individual B that in turn evokes a further response from A [Morgeson and Hofmann, 1999]. Although interactions can be framed in terms of stimulus/response events, we suggest that such reciprocal responses are better described as system feedback or synergy resulting in persistent attitudinal changes and behavioral changes rather than simple reactions to events. Examples of emergence as process resulting from intentional human activity are shown in Table 3.

Table 3: Examples of Emergence as Process

Example reference	Research focus
"A Design Theory for Systems That Support Emergent Knowledge Processes" [Markus, Majchrzak and Gasset, 2002]	Design requirements for providing IT support for knowledge processes that emerge from the unstructured interactions of variable sets of actors deliberating in dynamically evolving contexts.
"Protest in an Information Society: A Review of Literature on Social Movements and New ICTs" [Garrett, 2006]	Information and communication technologies (ICTs) are a central component in the emergence of social and activist movements. The goals, structures, maintenance, and evolution of movements are influenced by the social networks involved.
"Secondary Design: A Case of Behavioral Design Research" [Germonprez et al., 2011]	People engage in practices of secondary design, resulting in the change and evolution of new system trajectories.

Our extended example of emergence as process examines the collaborative creation of an online artifact in the form of a Wikipedia page [Germonprez et al., 2011]. The research describes processes of anchoring, negotiation, and reification as people design a Wikipedia page. The technology of Wikipedia is presented as given, but people's participation and effort is required to create content and form in a process of engaged, or secondary, design. Secondary design is an emergent process at multiple levels of interest including site functionality, page presentation, and information content. The article presents these processes in terms of dualities that "are not opposite ends of a dimension; rather, each pair complements and contrasts with the other such that, to understand one concept, we

must also understand the other” [Germonprez et al., 2011, p. 669]. Through the lens of emergence as process, secondary design represents ongoing interactions among people, between people and technology, and among technologies. Emergence as process emphasizes that states, as represented by patterns of behavior, attitudes, and beliefs of user/technology configurations, may be temporarily persistent but are also potentially mutable.

Process emergence suggests that to comprehend the structural and functional factors [Burton-Jones, 2005], timing [Abbott, 2001], improvisation [Ciborra, 1999; Orlikowski and Hofman, 1997], and design-in-use [Germonprez et al., 2011; Lin and Cornford, 2000] requires researchers to consider appropriate research methods when investigating emergent phenomenon. Methodological considerations include support for grounded, or bottom-up, analysis where emergence is evidenced but unanticipated (e.g., coordination and communication of underlying online activism), for top-down influence of emergent wholes on the constituent parts (e.g., feedback mechanisms resulting in affective, cognitive, and behavioral changes in actors), and support for the interaction of parts that result in novel emergence properties (e.g., system changes). In each of these cases, methodological considerations are necessary to provide the requisite flexibility needed to respond to trajectories that cannot be defined or understood *a priori*.

IV. A FRAMEWORK FOR EMERGENCE PHENOMENA

This research organizes three important forms of emergence discussed in the literature along two dimensions: simple/complex and internal/external view (Table 4). The simple/complex dimension captures differences between forms of emergence, in which the properties of the whole can be predicted by knowing the properties of the parts (simple), and forms of emergence where the whole has distinctly different properties (complex). The internal/external dimension reflects the perspective from which emergence phenomena are viewed: an internal perspective indicates that emergence occurs within the perceptions, attitudes, beliefs, or behaviors of an actor. Emergence from an external perspective indicates that it is the properties or structure of the observed entity that come into being through the interactions of their parts. Table 4 organizes forms of emergence.

Table 4: A Framework for Emergence in IS Research

	Simple	Complex
Internal	<p>Perceptual Emergence:²</p> <p>A perceptual focus meaning that something that was obscured becomes visible to the researcher or subject.</p> <p><i>Example: The sun emerged from behind the clouds.</i></p>	<p>Emergence as Process:</p> <p>Focuses on patterns, timing, and intensity of interactions of constituent parts. Interactions may be planned or inadvertent.</p> <p><i>Example: People secondarily design systems over time for their own tasks, context, and use patterns.</i></p>
External	<p>Associative Emergence:</p> <p>Constituent parts are associated or aggregated such that the properties of the whole can be predicted by attending to the properties of the constituent parts.</p> <p><i>Example: Organizational memory emerges from processes and practices at lower levels of the organization.</i></p>	<p>Combinatorial Emergence:</p> <p>Constituent parts are combined or fused such that the properties of the whole are distinct from the properties of the parts, and the parts themselves are transformed.</p> <p><i>Example: Organizational transformation emerges out of people’s accommodation to everyday contingencies, opportunities, and unintended consequences.</i></p>

V. DISCUSSION

There are no crisp lines of demarcation among forms of emergence. The purpose of this framework is not to label every emergent phenomena. Rather, the definitions of forms allow researchers to more clearly describe what actually is emergent in the phenomena. Thus, this research essay informs IS research in four ways. First, emergence is often used without attention to the specific form under study, the structural or functional changes to components, or the implications of the processes by which emergence occurs. By clarifying emergence within a framework, we aid researchers in articulating the origins of complex phenomena and choosing suitable methods for

² Again, perceptual emergence is a viable yet simple and internal form of emergence. We do not explicate its characteristics in this essay because its characteristics do not represent a collection of parts to a whole or a change in an object over time. Perceptual emergence is limited to the new observation of a steady-state object that was formerly hidden.

research. Explanation of many phenomena can be reduced to the properties of the parts in ways that permit prediction and increase the probability of successful interventions. But the ability “to reduce everything to simple fundamental laws does not imply the ability to start from those laws and reconstruct the universe” [Anderson, 1972, p. 393]. In this, understanding the configuration and timing of component interactions is necessary to understand phenomena and their persistence, as emergence is often contextually situated and is not easily generalized. We contend that widely used reductionist approaches to emergent phenomena are limited because the reductionist hypothesis does not imply a “constructionist” perspective. Differentiating between associative and combinatorial emergence has implications for research methods, the indeterminacy of outcomes (e.g., design science research), and the generalizability of knowledge claims.

Second, emergent phenomena whose properties come into being through the interactions of their components also produce changes in those components. Emergence results in change to social, organizational, and technical trajectories at multiple levels as emergent phenomena often result in persistent changes to their component parts. For example, the behaviors and attitudes of members of a group are changed by their interaction within the group. These changes may have persistence after dissolution of the group, resulting in belief changes that affect future group interactions [Lee and Dennis, 2012]. Understanding persistent change requires researchers to examine system structures and feedback over time as the sequence and temporal ordering through which emergence occurs may itself strongly influence the structural and functional relationships of parts. This feedback relationship thus alters the evident structures, functions, and persistence of emergent wholes. At the same time, emergent patterns may be indicative of underlying social and material constraints that increase the probability of specific emergent assemblages while reducing the likelihood of other assemblages. The social and technical components of systems are not infinitely mutable—we cannot realistically expect the emergence of high-level functional ordering from arbitrary components nor expect radical changes in social or technical norms [Kallinikos, 2004]. Functional synergies that result in less effortful cognitive and behavioral patterns may be more likely to emerge because they remain stable and require less input from participants. This would suggest a more holistic research focus on functional configuration and dependency interaction of parts rather than identification of independent non-interacting factors. Emergent phenomena of this type require the examination of system effects and attention to the sequence and temporal ordering of events through which emergence occurs [Abbott, 2001]. Although the outcomes of specific instances of emergence are not predicable, patterns of emergence indicate that the social and the technical coalesce in probabilistic ways.

Third, complex emergent phenomena produce context-dependent effects as emergent “wholes produce unique combined effects; many of these effects may be codetermined by the context and the interactions between the whole and its environments” [Corning, 2002, p. 63]. Researchers must examine how components at different levels combine to produce wholes [Burton-Jones, 2005; Kozlowski and Klein, 2000; Morgeson and Hofmann, 1999] and also recognize how different research perspectives may be required to understand the properties of the emergent wholes themselves. For example, the micro-level properties of water are understood based on knowledge of atomic interactions. However, the perspectives needed to account for holistic macro-level properties of water depend on context; understanding temperature changes in water requires thermodynamics; hydraulics are needed to understand the effects of force upon water; still other principles are needed to account for surface tension, adhesion, capillary action, surface water flow, and the global water cycle. Thus, the properties of an emergent phenomena that researchers attend to and the theoretical lenses they select change based on context [Corning, 2002]. For example, there are factors that correlate with successful Open Source Software (OSS) initiatives [Aksulu and Wade, 2010] but different principles are required to understand the complexity of emergent characteristics of specific OSS phenomena. Specific macro-level phenomena of OSS include the stability of the actual code, the interactions of participants during creation and maintenance of the OSS community [Kelty, 2009], the implementation of OSS in an organization, and the participation of companies in OSS development [Lee and Cole, 2003]. As noted by Niederman et al. [2006b] different levels of analysis are determined by the context of the researcher, and within each context different aspects of the phenomena are perceived to be salient and may require different research perspectives. We understand that influences may be upward from components to the whole, downward from the whole to the parts, between parts, and between the whole and the environment. This multilevel perspective suggests the need for combining research perspectives beyond reductionist approaches.

Finally, clarity regarding emergence requires the recognition of the effects of time and interaction, thereby highlighting the importance of appropriate research methods for apprehending emergent phenomena. Emergent outcomes such as organizational transformation or boundary-spanning practices show the difficulty in establishing predictive relationships in socio-technical systems through reductionist approaches. The ability of teams to overcome poor-fit technologies and achieve a high level of emergent performance [Fuller and Dennis, 2009] and the significance of time as a factor in collective usage [Burton-Jones, 2005] demonstrate the difficulty in understanding emergence with cross-sectional studies. Information system appropriation is an ongoing process between people, context, and technology such that new system forms emerge from the negotiation and reification of how these

characteristics interact in the world [Germonprez et al., 2011; Reimer and Johnston, 2012]. Emergence can, at times, require long-term commitment to understand and realize the changing nature of the IS-enabled world. The origins of qualitative novelty in high-level phenomena that originate from low-level components is fundamental to the rapidly moving and evolving world of information systems and their evolving trajectories. In all, research into emergent phenomena requires a deeper unpacking in an effort to comprehend the specific origins, persistence, and degree of indeterminacy of emergence phenomenon and processes.

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