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THEORIZING INFORMATION SYSTEMS AS TECHNOLOGY: MIGHT IT BE FRUITFUL?

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Theorizing Information Systems as Technology: Might it be Fruitful?

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Abstract

Information systems scholars have struggled with the field's fundamental relationship to technology. In particular, they have debated whether the IT artifact is unwisely taken for granted and whether or not it lies at the field's core. Here, applying Brian Arthur's general theory of technology, it is suggested that IS may itself be theorized as technology. From this perspective, new avenues for IS research may be opened up, in particular, for historical and other related studies where the unit of analysis is the technology itself and the focus is its evolution.

Keywords: technology, information systems, IT artifact, sociomateriality, evolutionary economics, organizing vision, historical studies

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Comments on this working paper are welcomed by the author!

1. Introduction

Information systems (IS) scholars have struggled over the last decade with the field's fundamental relationship to technology. Most notably, they have been divided in responding to a call by Orlikowski and Iacono (2001) to focus more substantially on the "IT artifact," understood as "bundles of material and cultural properties packaged in some socially-recognizable form such as hardware and/or software," (p. 121), which have been under-theorized, taken for granted, treated as "relatively stable, discrete, independent, and fixed," and "unproblematic" in IS research. This constitutes something of a paradox, as the IT artifact is arguably, on the face of it, the field's "core subject matter." Seeking reform, the authors call for theorizing in which the IT artifact is understood as: (i) not "natural," neutral, universal, or given; (ii) not independent, but rather embedded in time, place, discourse, and community; (iii) not discrete, but typically made up of often fragile and fragmentary components, which must work together; (iv) not fixed, but emerging from ongoing social and economic practices; (v) not static or unchanging, but dynamic.

Responses to the Orlikowski and Iacono call have varied. Several are included in a collection by King and Lyytinen (2006a) addressing the future of the IS field. A principal struggle revolves around whether the IT artifact indeed lies at the field's center. Weber (2003) thinks not, stating, "…I believe the core, if one exists, will not lie in theories that account for information technology-related phenomena. Rather it will lie in theories that account for information-systems phenomena." (p. 48) (Weber favors ontological theories of representation as the foundation for IS research.) Benbasat and Zmud (2006) modify their previously presented and controversial "nomological net" (Benbasat and Zmud, 2003) to feature information systems as the central construct, offering a definition: "We conceptualize an information system… as the application of one or more IT artifacts to enable or support some task(s) embedded with structure(s) that themselves are embedded within context(s)." (p. 301). On the whole, the contributors are in agreement that IT and IS should be differentiated, but how they should be theoretically related is not settled.

In the present paper, I won't further belabor this well worked-over debate among IS scholars about the core of the field as such (see, e.g., Alter, 2008; King and Lyytinen, 2006b). Rather, I will introduce and explore a recently advanced theory, not my own, which, I conjecture, can be readily applied to respond precisely to the Orlikowski and Iacono call, while also offering insights helpful to the IS field and its research. The theory is a general theory of technology presented by Brian Arthur (2009) in his provocative book, *The Nature of Technology*, which deserves wider recognition among IS scholars. While the theory is informally presented in the book, it is at once simple and rigorous in its basics, and powerful in its implications for our understanding of technology. Moreover, it is the very opposite of a theory which takes the technological artifact for granted. Might then an "Arthurian approach" to theorizing the IT artifact in the IS context be fruitful? Before taking this question up directly, it will be helpful to provide additional background.

2. Background

Interestingly, at the time of their call, Orlikowski and Iacono (2001) noted that the IS field was then not alone in seemingly taking the technological artifact for granted. The problem also persisted in related organizational and social studies. They lamented: "Processes such as innovation and change are conceptualized largely in socio-economic terms, while 'things' are not considered or are treated as self-evident. … Technology, as the quintessential 'thing,' dissipates into the atmosphere around us, or it becomes emblematic of our 'age.' We throw it up as a banner of our times, but then instantly let it recede from view by stereotyping or ignoring it." (p. 122). This is so even though management scholars have long recognized the importance of technology to organizations, with studies dating back at least to the 1950s (e.g. Thompson and Bates, 1958; Woodward, 1958). Too, that technology should be understood to be "socially constructed" (Bijker, et al, 1993) has also come to be widely accepted by researchers.

More recently, studies of *sociomateriality* (Orlikowski and Scott, 2009) have come to prominence, as a way to bring technology more thoroughly into organizational studies. The idea is to reject the traditional separateness of people and technology as such and "focus on agencies that have so thoroughly saturated each other that previously taken-for-granted boundaries are dissolved…. (to) move away from focusing on how technologies influence humans, to examining how materiality is intrinsic to everyday activities and relationships." (p. 455) Leonardi, Nardi, and Kallinikos (2012) provide a recent collection addressing materiality and organizing. Materiality itself is understood somewhat differently by the contributors. Regardless, in the case of software, one of the most prominent artifacts of our time, it is recognized that it is more important for its form and function than for the physical materials in which it may be represented (Kallinikos, 2012).

Organizational sociologists are not alone in struggling with the role of technology in their theories and studies. Evolutionary economists have long claimed that technology deserves a more prominent place in economic theories. Metcalfe (2010) provides a recent review, finding that in modern economic theory:

> "(T)he primitive notion of technology runs in terms of a specification of the quantities of various inputs required to produce a given quantum of a particular kind of output over some definite time interval, and given the understanding of the state of the art in the minds of those operating the process. This perspective of technology as a menu (for it is less than a blueprint) appears most obviously in the theory of production and consequently in the theory of the firm, which is taken to be the controlling and managing unit of any production activity." (p. 155)

While the primitive notion works well enough in many static and stationary analyses:

> "It is when we turn to problems of growth and development, and thus to questions of innovation and technological change, that the menu approach to technology becomes problematic, precisely because growth and development are

> so closely connected to changes in technology. … One has to move beyond the idea of technology as the menu of inputs and outputs to a more finely detailed understanding of the multiple dimensions that characterize different ways of doing things. This is the basis for the idea that a blueprint or recipe lies behind a particular menu, specifying what it means to get things done. But just as there is more to the blueprint than a menu so there is more to the actual doing than is specified in a recipe. What has to be added is knowledge of who is using the recipe because their personal knowledge and skills make a difference to what the recipe leads to." (p. 157).

But useful knowledge and skills are unevenly distributed in the economy, and moreover, the profit motive stimulates this through continuous search for better goods and services and means of production. Useful knowledge and technology are "restless," and "there are always good reasons to know differently." (p. 160) As a consequence, where technology is concerned, the economy can't be considered a system in equilibrium, as it is in neoclassical theory. Rather, it must be seen as dynamic, in flux, and as an ongoing problem-generating and problem-solving structure.

This basic argument underpins much of the research in evolutionary economics, reviewed by Dosi and Nelson (1994). Evolutionary theories aim to "explain the movement of something over time, or to explain why that something is what it is at a moment in time in terms of how it got there; that is, the analysis is expressly dynamic. …The explanation involves both random elements which generate or renew some variation in the variables in question, and mechanisms that systematically winnow on extant variation. Evolutionary models in the social domain involve some processes of imperfect (mistake-ridden) learning and discovery, on the one hand, and some selection mechanism, on the other." (pp. 154-155) In short, such theory seeks to understand how a society or economy *learns and advances* (or not). Notably, it meshes with organization theory suggesting that relatively invariant *routines* (Nelson and Winter, 1982; Pentland and Feldman, 2008) guide behaviors. Dosi and Nelson: "Precisely because there is nothing which guarantees, in general, the optimality of these routines, notional opportunities for the discovery of 'better' ones are always present. Hence, also the permanent scope for search and novelty. Putting it another way, the behavioral foundations of evolutionary theories rest on learning processes involving *imperfect adaptation* and *mistake-ridden discoveries*. This applies equally to the domains of technologies, behaviors and organizational setups." (p. 159)

Brian Arthur's research is very much in the evolutionary economics tradition. His interest in technology stems partly from his early work exploring increasing returns to the adoption of certain new products, which might win out over competitors, if they are able to dominate the market early enough (Arthur, 1989). Arthur came to write his recent book, after finding that, despite much good work on technology, something was missing: "We have analyses of the design process; excellent work on how economic factors influence the design of technologies, how the adoption process works, and how technologies diffuse in the economy. We have analyses of how society shapes technology, and of how technology shapes society. And we have meditations on the meaning of technology, and on technology as determining—or not determining—human history. But we have no agreement on what the word 'technology' means, no overall theory of how technologies come into being, no deep understanding of what 'innovation' consists of, and no theory of evolution for technology. Missing is a set of overall principles that would give the subject a logical structure, the sort of structure that would help fill these gaps." (p. 13) Arthur's book takes up this challenge.

In the present paper I do not attempt a broad assessment of Arthur's theory. Rather, I take it more or less as it is offered and seek to apply it to the case of information systems, to see what insights might be gained. The paper continues as follows. In the next section, I provide a brief summary of Arthur's theory. Following this, I apply the theory to IS. The paper concludes after an extended discussion.

3. Arthur's Theory of Technology

Brian Arthur's theory of technology, as presented in his book, is inspired by his quest to understand technology and its relationship to the economy, and more subtly, the ways in which economic development is intertwined with technology development, as he states in the book's preface:

> "I became fascinated with how the economy develops and builds out. It was clear to me that the economy was in no small part generated from its technologies. After all, in a sense an economy was nothing more than the clever organization of technologies to provide what we need." (p. 1)

Arthur develops and presents his theory over eleven book chapters. He begins by addressing basic questions, previewing where he will ultimately arrive, which is to explain technological development as a process of combinatorial evolution:

> "Early technologies form using primitive technologies as components. These new technologies in time become possible components-- building blocks-- for the construction of further new technologies. Some of these in turn go on to become possible building blocks for the creation of further new technologies. In this way, slowly over time, many technologies form from an initial few, and more complex ones form using simpler ones as components. The overall collection of technologies bootstraps itself upward from the few to the many and from the simple to the complex. We can say the technology creates itself out of itself." (p. 21)

Arthur begins with a broad definition of technology as "a means to fulfill a human purpose," (p. 28), "a device, or method, or process," (p. 29), which is subsequently refined to evoke more familiar notions of technology as that achieved by applying scientific understandings of physical phenomena. The theory he develops does not ultimately depend on how broadly or narrowly the definition is applied, which, as will be seen, makes it easily applicable to information systems as technology, our present interest.

Arthur then asserts a set of "three fundamental principles" from which his theory will be developed:

> "The first will be … that technologies, all technologies, are combinations. This simply means that individual technologies are constructed or put together- combined- from components or assemblies or subsystems at hand. The second will be that each component of technology is itself in miniature a technology. … And the third… will be that all technologies harness and exploit some effect or phenomenon, usually several." (p. 23)

The first two principles, asserting the combinatorial and recursive aspects of technology, are straightforward, while profound. The third principle, that all technologies harness and exploit some effect or phenomenon, is easily understood for traditionally understood technologies tied closely to nature and the physical world. Thus, for instance, "That certain objects—pendulums or quartz crystals—oscillate at a steady frequency is a phenomenon. Using this phenomenon for time keeping constitutes a principle, and yields from this a clock." (p. 49). However, because the definition is very broad, it can be stretched to include very different engineered means, such as legal systems, monetary systems, and contracts as technologies, where the notion of what effect or phenomenon is being harnessed is less conventional and more subtle, and is anchored in human behavior. Recognizing and wishing to allow for this, Arthur introduces the notion of a *purposed system*, defined as "the class of all means to purposes, whether physically or non-physically based," to represent this more expansive view of technology. Whether this is to the taste of those committed to traditional technological studies or not, it provides the opening, indeed an invitation, to explore the application of Arthur's theory to information systems.

Arthur goes on in subsequent chapters to address and build upon these basic ideas. Drawing from the third principle, he introduces the concept of technological domains:

> "As families of phenomena—the chemical ones, electrical ones, quantum ones—are mined into and harnessed, they give rise to groupings of technologies that work naturally together. The devices and methods that work with electrons and their effects—capacitors, inductors, transistors, operational amplifiers—group naturally into electronics; they work with the medium of electrons, and therefore 'talk' to each other easily." (p. 69)
>
> "I will call such clusters—such bodies of technology—*domains*. A domain will be any cluster of components drawn from in order to form devices or methods, along with its collection of practices and knowledge, its rules of combination, and its associated way of thinking." (p. 70)

In contrast to a technology, a domain does no job, but serves rather as a toolbox from which to draw components and practices. More broadly: "A domain is a realm in the imagination where designers can envisage what can be done—a realm or world of possibilities." (p. 80). "Design in engineering begins by choosing a domain, that is, by choosing a suitable group of components to construct a device from." (p. 71) And while an individual technology, e.g., a particular computer, may be invented, its associated domain(s), e.g. digital electronics, accrues gradually and may even come to form one or more industries.

Arthur continues in subsequent chapters to build out his theory and its ramifications. In Table 1, I have attempted a brief summary of the theory tailored to present purposes, drawing on Arthur's own words. It elaborates on the basics: (1) the definition of technology; (2) the three fundamental principles; (3) purposed systems; and (4) technological domains, as already introduced. It then further addresses: (5) engineering practice; (6) novel technologies and how they arise; (7) technology development; (8) redomaining of technologies; (9) technology evolution; and (10) the economy as an expression of the technologies employed. Rather than repeat here what is contained in this latter portion of the table, I leave the perusal of the summary to the reader. The ambitious character and scope of Arthur's theory of technology should be apparent.

4. Application to Information Systems

Might information systems (IS) be fruitfully theorized as technology, in the Arthurian sense? The suggestion here is that it might be. In Table 1, I take an exploratory stab at this application. With regard to the basic definition, it should be clear enough that basic information technology (IT) and its devices provide an easy fit. But I posit that information systems (IS), though they are more organizational devices, than they are physical or even digital devices, also represent a class of technology. To facilitate matters, I focus on an IS subclass, enterprise systems, such as ERP (Enterprise Resource Planning) and CRM (Customer Relationship Management), in further application of the theory. As a cautionary note, this application exercise is intended to be illustrative more than definitive.

With regard to the three fundamental principles, I suggest that application of the first two to IS is straightforward, but the third is not. What is potentially problematic is a clear identification of the phenomena or "exploitable effect" being "harnessed" in developing an IS as a technology, at the unifying level of an ERP or CRM. While physical effects are easily identified lower in the combinatorial technological system underpinning enterprise systems, where basic IT is employed, the harnessed effects at the unifying level may be more human and organizational. I return to this point below.

Elsewhere, the notion of technological domains seems readily applicable to IS. Both ERP and CRM have their respective tool kits—software components, methods, routines—from which individual instances may be engineered. Each implementation also poses a new problem and where eventually successful, it then contributes to the solution repertoire, for example by providing a new template to the toolkit. Both ERP and CRM have also been redomained over the course of their histories, ERP achieving break-through prominence when its platform was moved to client server and relational database technologies, while CRM, already popular as an application package, gained new impetus when reconceived as a software-as-a-service.

One interesting challenge in the application of the theory to IS arises in the case of novel technologies, which more broadly often come about through invention. This notion is problematic in the IS context. ERP and CRM were not invented, but rather arguably arose through new *organizing visions*, that were then used to promulgate them. For instance, the ERP vision articulated the integration of financial, operational, and human resource systems that had not previously been tied together. The CRM vision promised a unifying view of the customer. In general, novel IS do not appear to be invented as such. Rather they emerge on the playing field of practice and come to be recognized in the community amid contentious claims made as to their novelty, practicality, and worth (Ramiller and Swanson, 2003).

The balance of the application exercise, concerning technology development, technology evolution, and the economy yields no further problems. The theory applies readily to IS. The reader is referred to Table 1 for the particulars.

In sum, the brief application exercise suggests that Arthur's theory may be applied to IS, and that IS may hence be conceived as a family of technologies. If there is a remaining concern, it may be that the illustrative application of Arthur's theory to IS comes maybe *too easily*. The present observations are obviously fragmentary. It remains to attempt a more thorough application, such as a case study, that would be more convincing of the insights that might be derived from a deeper analysis.

5. Discussion

What then are the ramifications for further theorizing information systems as technology, in the Arthurian sense?

First, it allows IS theory to be developed as part of technology theory more broadly. It provides a new avenue beyond the ones already exploited. Because IS are characterized as technology, rather than as the *application* of technology, as if this was somehow a fundamental distinction, it also provides for reconciliation of the definitional debate. It is noteworthy that in Arthur's concept, all technologies are in essence applications of what we know and what we can do with it. What arguably distinguishes IS as technology is that it is developed at a higher level of the combinatorial hierarchy and at a higher level of abstraction than the underlying IT.

Information systems such as ERP or CRM are often conceived and promulgated through organizing visions that explicate this higher level of abstraction (Swanson and Ramiller, 1997; Wang and Ramiller, 2009). These visions speak to what the IS are about, the purposes they serve, and how to be successful with them. They try to tell the story of the technology and why it should be widely embraced. Within Arthur's framework, the functionality of the IS as a technology, the task it carries out, is likely to be directly addressed by the organizing vision. Less obvious in the vision, as observed above, may be the effect that is harnessed by the IS as a technology. However, organizing visions may be studied by scholars to probe this aspect of the technology.

When it is asked of ERP or CRM, what is really new here, this may be one way to ask what is really being harnessed such that these technologies are recognizably distinct from others. In the case of ERP, the vision arguably stemmed from the harnessing of client-server technology and the development of modularized generic packaged software and associated configuration templates, exemplified by SAP's R/3 product, which enabled customers to develop and implement "best practice" business process solutions, while replacing mainframe-based legacy systems (see, e.g., Klaus, Rosemann and Gable, 2000). But with all that has been written to date about ERP, the story of its development as a technology, from the perspective of Arthur, has not yet been told, to my knowledge.

As a second ramification, then, Arthur's perspective shifts the focus of research to dynamic analyses more than comparative statics, so as to better understand change. Accordingly, understanding ERP as a technology demands that we grasp how it initially emerged and diffused through an organizing vision, for instance, but also how it has since evolved, and even served as a platform for newer technologies. This aspect of ERP has yet to be much explored, to my knowledge. While the IS field has benefitted from numerous studies to date of ERP, many have been situated in the field at moments in time where implementations have taken place, and where lessons have been individually drawn and compared to those of prior studies, but largely in the absence of a broader notion of an evolving technology, where individual lessons learned may or may not be stable or enduring.

Thus, as a third ramification, the Arthurian perspective lengthens the time frame for IS studies, both backward and potentially forward. It calls for both more historical studies, so that IS developmental paths can be better understood, but arguably also more grounded futures research, to enable us to grasp where current paths are taking us and whether we want to continue on them or, in some cases, redirect them to better ends. It is here that IS research might also better capture the interests of practitioners who track the assessments and prognostications of Gartner and other groups, who are always prepared to speak to the ebbs and flows, and even the "hype cycles" (Fenn and Raskino, 2008), associated with new technologies. Solidifying the research base behind such work would make a valuable contribution.

With regard to historical studies, which have been previously called for, but so far little delivered by IS scholars (see Mason, McKenney, and Copeland, 1997; Bannister, 2002), the idea of telling the larger IS story as an evolution of technologies, threading together the individual technologies that have marked the development of information systems over decades, is an exciting one, to my mind. Case studies of organizing visions may be particularly useful as one approach (Swanson, 2013). Biographical studies of a certain kind have also been suggested (Williams and Pollock, 2012). But these are merely two illustrations of approaches that might be taken where the unit of analysis would be the IS technology itself.

6. Conclusion

Finally, to return to where this essay began, it may be observed that Arthur's theory of technology indeed responds well to the Orlikowski and Iacono (2001) call for an understanding of the IT artifact as not "natural" or given, not independent but embedded, not discrete but made up of components, not fixed but emerging, and certainly not static but dynamic. What is interesting is that while much recent research has taken a rather sophisticated social science turn toward reconciling technology and organization through the introduction of weighty concepts such as sociomateriality, Arthur offers up an alternative, parallel avenue that should be especially appealing to those with more of an interest in technology and its developmental path and economics, and a rather straightforward theoretical approach that may, perhaps, be taken without the heavier baggage. Of course, the insights gained from each approach may be rather different, reflecting the different orientations, though I believe they should ultimately be complementary to our understandings. There is some evidence that there is potential for this. Yoo, et al (2012) draws from Arthur's work as well as the sociomateriality literature in commenting on the nature of innovation in the "digitized world." Yoo (2012) also takes an evolutionary perspective. However, it remains to explore the opportunities offered by Arthur's technology theory more fully. Here I have attempted to set such exploration in motion. Following the suggestion by King and Lyytinnen (2004), I have reached a bit, even though what this might offer the IS field lies beyond our current grasp.

7. References

Alter, S. (2008). "Defining IS as work systems: Implications for the IS field," *European Journal of Information System*s 17, 448-469.

Arthur, B. (1989). "Competing technologies, increasing returns, and lock-in by historical events," *Economic Journal* 99, 116-131.

Arthur, B. (2009). *The nature of technology*. New York: Free Press.

Bannister, F. (2002). "The dimension of time: Historiography in information systems research," *Electronic Journal of Business Research Methods* 1(1), 1-10.

Benbasat, I., and Zmud, R. W. (2003). "The identity crisis within the IS discipline: Defining and communicating the discipline's core properties," *MIS Quarterly* 27(2), 183-194.

Benbasat, I., and Zmud, R. W. (2006). "Further reflections on the identity crisis." In King and Lyytinen (2006), 300-306.

Bijker, W. E., Hughes, T. P., and Pinch, T. J., Eds. (1993). *The social construction of technological systems*. Cambridge, MA: MIT Press.

Dosi, G., and Nelson, R. R. (1994). "An introduction to evolutionary theories in economics," *Journal of Evolutionary Economics* 4, 153-172.
Fenn, J., and Raskino, M. (2008). *Mastering the hype cycle*. Boston: Harvard Business Press.
King, J. L., and Lyytinen, K. (2004). "Reach and grasp," *MIS Quarterly* 28(4), 539-551.
King, J. L., and Lyytinen, K., Eds. (2006a). *Information systems: The state of the field*. Chichester, UK: Wiley.
King, J. L., and Lyytinen, K. (2006b). "The market of ideas as the center of the field," *Communications of the AIS* 17, 2-19.
Klaus, H., Rosemann, M., and Gable, G. (2000). "What is ERP?", *Information Systems Frontiers* 2(2), 141-162.
Leonardi, P. M., Nardi, B. A., and Kallinikos, J., Eds. (2012). *Materiality and Organizing*. Oxford: Oxford University Press.
Mason, R. O., McKenney, J. L., and Copeland, D. G. (1997). "Developing a historical tradition in MIS research," *MIS Quarterly* 21(3), 257-278.
Metcalfe, J. S. (2010). "Technology and economic theory," *Cambridge Journal of Economics*, 34, 153-171.
Nelson, R., and Winter, S. (1982). *An evolutionary theory of economic change*. Cambridge, MA: Belknap Press.
Orlikowski, W. J., and Iacono, C. S. (2001). "Desperately seeking the 'IT' in IT research: A call to theorize the IT artifact," *Information Systems Research* 12(2), 121-134.
Orlikowski, W. J., and Scott, S. V. (2009). "Sociomateriality: Challenging the separation of technology, work and organization," *Academy of Management Annals* 2(1), 433-474.
Pentland, B. T., and Feldman, M. S. (2008). "Designing routines: On the folly of designing artifacts, while hoping for patterns of action," *Information and Organization* 18, 235-250.
Ramiller, N. C., and Swanson, E. B. (2003). "Organizing visions for information technology and the information systems executive response," *Journal of MIS* 20(1), 13-50.
Swanson, E. B. (2013). "Illuminating organizing vision careers through case studies," *Proc. of AMCIS*, Chicago, available online.
Swanson, E. B., and Ramiller, N. C. (1997). "Organizing visions in information systems innovation," *Organization Science* 8(5), 458-474.
Thompson, J. D., and Bates, F. L. (1958). "Technology, organization, and administration," *Administrative Science Quarterly* 1, 325-343.
Wang, P., and Ramiller, N. C. (2009). "Community learning in information technology innovation," *MIS Quarterly* 33(4), 709-734.
Weber, R. (2003). "Still desperately seeking the IT artifact," *MIS Quarterly* 27(2), iii-xi.
Williams, R., and Pollock, N. (2012). "Moving beyond the single site implementation study: How (and why) we should study the biography of packaged enterprise solutions," *Information Systems Research* 23(4), 1-22.
Woodward, J. (1958). *Management and technology*. London: HMSO.
Yoo, Y. (2012). "Digital materiality and the emergence of an evolutionary science of the artificial," in Leonardi, Nardi, and Kallinikos (2012), 134-154.

Yoo, Y., Boland, R. J., Lytytinen, K., and Majchrzak, A. (2012). "Organizing for innovation in the digitized world," *Organization Science* 23(5), 1398-1408.

Table 1. Arthur's Theory of Technology and its Application to IS Context

Theory of Technology	**Application to IS Context**
Basic definition: "…a technology is a means to fulfill a human purpose. … (It) may be a method or process or device." (p. 28). "(It) does something. It executes a purpose. … (It may be spoken of as) an *executable*." (p.29) "(It) supplies a *functionality*. This is simply the generic task it carries out." (pp. 29-30). Further: "A technology embodies a sequence of operations; we can call this its 'software.' And these operations require physical equipment to execute them; we can call this the technology's 'hardware.' If we emphasize the 'software' we see a process or method. If we emphasize the 'hardware,' we see a physical device." (p.31).	The basic definition is easily applied. Information technology (IT) represents a special class of technology, as also does digital technology, which, in the modern context, serves as the foundation for the former. Information systems (IS), which applies IT to human enterprise, represents a class of technology in its own right. While it employs physical devices, IS itself is more an organizational device. Like all technologies, IS necessarily has a *performative* aspect in its execution, which in its case rests on organizational learning. A subclass of IS technology is enterprise systems, including ERP (Enterprise Resource Planning) and CRM (Customer Relationship Management).
1st fundamental principle: "…all technologies are combinations. … Individual technologies are constructed or put together… from components or assemblies or subsystems at hand." (p. 23). Too: "The primary structure of a technology consists of a main assembly that carries out its base function plus a set of subassemblies that support this." (pp. 33-34).	The application of this principle to the IS context is straightforward, as it incorporates basic system design and building concepts and methods. ERP represents a family of systems, for instance, as does CRM, as instantiated by product and service offerings in these categories. Still, this may not be the only or even best representation of the combinations that characterize ERP and CRM.
2nd fundamental principle: "…each component of technology is itself in miniature a technology." (p. 23). "Technologies…have a recursive structure. They consist of technologies within technologies all the way down to the elemental parts." (p. 38)	The application of this principle to the IS context is also straightforward, though it may stretch the thinking of some with regard to the use of the term. Computer programmers may appreciate this insight, however. In the case of ERP and CRM, even a low-level software subroutine can be understood as a technology and its instantiation.
3rd fundamental principle: "…all technologies harness and exploit some effect or phenomenon, usually several." (p. 23). "A technology is always based on some phenomenon or truism of nature that can be exploited and used to a purpose." (p.46). "(Physically-based) phenomena … exist independently of humans and of technology." (p. 49). "In practice, before phenomena can be used for a technology, they must be harnessed and set up to work properly." (p. 49). A technology in essence is "a collection of phenomena captured and put to use." (pp. 50-51).	The application of this principle to the IT context is relatively straightforward, but to the IS context, it is not. It is easy to identify the phenomena harnessed to enable digital storage and transmission, for instance. But the functionalities provided by IS are typically organizational in nature, and rely on human and social phenomena, not just physical phenomena. In the case of ERP, it arguably harnesses client server technology, standard business routines, and packaged business software technology. In the case of CRM, it arguably harnesses sales and customer contact routines with a centralized customer data base and marketing analytics.
Purposed systems: "Conventional technologies, such as radar and electricity generation, feel like 'technologies' because they are based upon physical phenomena. Nonconventional ones, such as contracts and legal systems, do not … because they are based upon nonphysical 'effects'- organizational or behavioral effects, or even logical or mathematical ones in the case of algorithms." (p. 55) "(We) have really been talking about a class of systems: a class I will call *purposed systems*. This is the class of all means to purposes, whether physically on non-physically based." (p. 56)	IS are thus *purposed systems* based more immediately on nonphysical effects, such as organizational, behavioral, and computational effects, than they are on physically-based effects. Foundational IT is based substantially on physically-based effects, such as silicon chip technology, or wireless digital transmission technology.

Domains: "As families of phenomena… are mined into and harnessed, they give rise to grouping of technologies that work naturally together." (p. 69) "A domain (is) any cluster of components drawn from in order to form devices or methods, along with its collection of practices and knowledge, its rules of combination, and its associated way of thinking." (p. 70). "A domain … does no job; it merely exists as a toolbox of useful components to be drawn from, a set of practices to be used." (p. 71). "Design in engineering begins by choosing a domain, that is, by choosing a suitable group of components to construct a device from." (p. 71). "A change in domain is the main way in which technology progresses." (p. 74)	Domains are important to IS progress. ERP emerged from relative obscurity when it was re-domained from a mainframe computing application to client-server computing and relational databases, as instantiated by the SAP R/3 product. CRM received a boost when it was re-domained from an in-house computing application package to software-as-a-service, as instantiated by Salesforce.com's offering.
Engineering: "In general, (engineers) design and construct artifacts. They also develop methods, build test facilities, and conduct studies to find out how … solutions will work in practice." (p. 90). "*Standard engineering* is the carrying out of a new project, the putting together of methods and principles that are known and accepted. ... (producing) a new instance of a known technology." (p. 91). But: "… *a new project always poses a new problem*." (p. 95). Hence: "…a finished design is a set of solutions to a (new) set of problems." (p. 96). Further: "(If) used often enough, a solution… becomes a module… encapsulated in a device or method … available for standard use. It becomes a technology itself." (p. 102).	These notions of engineering problems and solutions are well known in the IS context. In the context of ERP, standard engineering is represented by one firm's adoption and implementation of a selected package. Each firm typically articulates unique requirements (the new problem) and configuring the package to meet these may provide a new template potentially available for use by other, later adopters. ERP diffusion is greatly facilitated by the use of such templates, which become part of ERP technology.
Novel technologies: "…a radically new (novel) technology …uses a principle new or different to the purpose at hand." (p. 108). An invention arises by "linking, conceptually and in physical form, the needs of some purpose with an exploitable effect (or set of effects)." (p. 109). Thus: "Novel building blocks arise in three possible ways: as solutions to standard engineering problems…; as non-deliberate inventions…; or as inventions proper, radically novel solutions that use new principles…" (p. 130)	The notion of novel technology can be problematic in the IS context. ERP and CRM as novel technologies were not invented as such. Rather, they arose through new *organizing visions*. In the case of ERP, the vision articulated the integration of systems (financial, logistic, and HR) that had not previously been tied together through a common database and interface, an exploitable effect. The promise was better coordination of decisions at the firm level.
Technology development. "As a technology becomes a commercial… proposition, its performance is 'pushed'." (p. 132). "Developers can overcome limitations often simply by replacing the impeded component… by one that works better." (p.133). "But they can also work around (an obstacle) by adding an assembly… that takes care of it." (p. 134). Thus, "technologies elaborate as they evolve. They add 'depth' or design sophistication to their structures. They become more complex." (p. 135). In maturity: "The old design, the old principle, tends to be locked in." (p.138) "When a new circumstance comes along …, it is easier to reach for the old technology- the old base principle- and adapt it by 'stretching' it to cover the new circumstances." (p. 140). "Eventually the old principle, now highly elaborated, is strained beyond its limits and gives way to a new one." (p. 141).	These development insights apply readily to the IS context. Prior to the emergence of ERP, firms commonly developed and maintained systems in house to provide much of the same functionality. Performance was constantly pushed through the adding of new features to meet new needs, and to overcome problems such as poor ease of use. These "legacy systems" became over-elaborated and all the harder to maintain. They also rested on expensive mainframe platforms. Finally, as the new millennium approached, firms' exposure to the Y2K bug substantially undermined the old base principle of in-house custom mainframe development. Firms made the move to new packaged (often "plain vanilla") solutions that promised to be more sustainable and less costly of maintenance.

Redomainings. "But domains are more than the sum of their individual technologies. They are coherent wholes… whose coming into being and development has a character that differs from that of individual technologies. They are not invented; they emerge, crystallizing around a set of phenomena or a novel enabling technology, and building organically from these." (p. 145). "And as the new domain arrives, the economy encounters it and alters itself as a result." (. 163).	Redomaining is easily recognized in the IS context. Web technology represents an important example, as it has changed the way content is accessed and presented, affecting both ERP and CRM. Content management systems arose as a novel technology to provide Web pages with enterprise data, for instance. More recently, smart phone apps have emerged to compete with browser-based Web access.
Technology evolution. "The presence of opportunity niches calls novel technologies into existence." (p. 174). "Existing technologies used in combination provide the possibilities of novel technology: the potential supply of them. And human and technical needs create opportunity niches: the demand for them. As new technologies are brought in, new opportunities appear for further harnessing and further combinings. The whole bootstraps its way upward." (p. 176).	The evolution of IS historically can be understood as a series of responses to opportunity niches created over time. The original management information systems (MIS) were created to provide managers with operational data summarized and tailored to their needs. ERP promised to integrate operational systems across the firm, to better coordinate efforts across traditional functions. CRM aimed to unify the views of the customer across the business. Big Data now seeks to exploit the explosion of data gathered by today's systems, with new analytics providing insights and understandings not previously obtainable.
The economy. May be defined as: "the set of arrangements and activities by which a society satisfies its needs." (p. 192). "The economy is an expression of its technologies… (which) form its skeletal structure." (p. 193). "The economy … emerges from its technologies. It constantly creates itself out of its technologies and decides which new technologies will enter it. … Technology creates the structure of the economy, and the economy mediates the creation of novel technology (and therefore its own creation)." (p. 194). "It follows that the economy is never quite at stasis." (p. 199). "It exists perpetually in a process of self-creation. It is always unsatisfied." (p. 200).	Information systems are a vital component of the economy's skeletal structure. At the most basic level, IS enables firms to transact with consumers and each other. It also supports the business technologies that embody the production functions of firms and industries more broadly. The rise of online shopping rests heavily on firms' IS, as well as on new IT in the hands of consumers, and illustrates how the economy is thereby currently being recreated around this new structure and its functionality.