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Information Technology: Principles, Methods, and Theory

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Information Technology: Principles, Methods, and Theory

4.1 Introduction

Information technology (IT), in the narrow sense in which the term is used in particular in North America, is the newest computing discipline to emerge over the past 20 years or so. The Computing Accreditation Commission of ABET, the primary accreditation agency for programs in computing, engineering, and technology in the United States, and increasingly beyond, first promulgated separate accreditation criteria for programs in IT in 2002. The Association for Computing Machinery (ACM) and Computer Society of the Institute of Electrical and Electronic Engineers (IEEE-CS) published its first model curriculum for programs in IT in 2008 (Lunt et al., 2008) although IT was mentioned already in the 2005 overview volume (JTFCC, 2005) in which an ACM, IEEE-CS, and Association for Information Systems (AIS) joint task force compared the various computing disciplines (http://www.acm.org/education/education/curric_vols/CC2005-March06Final.pdf).

Before discussing research in IT, it is good to make a distinction between the broader use of the term “information technology” and the narrower sense in which the term will be used in this chapter. In the broader sense, the term “information technology,” which was first coined by Leavitt and Whisler (1958), refers to the whole of computing and includes all the computing disciplines, including computer engineering, computer science, information systems (IS), software engineering, and the myriad of emerging computing disciplines. In this broader sense, “IT” is therefore more or less synonymous with the terms “computing” and “informatics.”

In the narrower sense, the term “information technology” is defined as follows by Lunt et al. (2008, p. 9):

IT, as an academic discipline, is concerned with issues related to advocating for users and meeting their needs within an organizational and societal context through the selection, creation, application, integration and administration of computing technologies.
With mathematics serving as the foundation, modern computer science was essentially born with the advent of the digital computer, proceeded in theory in 1931 by Kurt Gödel’s incompleteness theorem and 1936 Alan Turing’s and Alonzo Church’s formalization of the concept of an algorithm. The first computerized business applications of the 1950s, often called electronic data processing, gave birth to the field of IS. Other scientific and engineering computing applications gave rise to software and computer engineering. By the 1990s, with the growing complexity of computing technologies, especially with the wide scale of integration provided by the Internet, IT emerged as a separate computing discipline primarily because of the workforce development needs (Lunt et al., 2008; Gowan and Reichgelt, 2010) to support the infrastructure. IT programs evolved because institutions heard from potential employers of graduates from computing programs that computer science programs often did not impart the more practice-oriented system and network administration skills in their graduates, focusing instead on the more theoretical aspects of computing. Programs in IS, on the other hand, often did not instill the required technical knowledge in their graduates, concentrating instead on issues concerning the management and use of IT in organizations.

4.2 Identity of the Field of IT

So, unlike many other new disciplines, the field of IT did not emerge out of a need to answer novel research questions, or out of a need to approach existing research questions through new methodological approaches. The discipline of IS arose out of the realization that questions regarding the use of computing technologies within organizations were not addressed sufficiently well in, for example, social and/or organizational psychology, sociology, or computer science. And one can argue that the discipline of cognitive science arose out of the realization that there was a greater need for theory building regarding and modeling of cognition than was possible in the main other discipline studying cognition, cognitive psychology. At the time of the emergence of cognitive science, psychology was still dominated by the behaviorist mind-set and attempted to explain every cognitive behavior simply in terms of the stimuli the individual received and the responses produced. Any speculation about the internal processes that mediated between stimuli and responses was frowned upon. Cognitive science was less beholden to this tradition and used the new methodology of computer modeling to approach the study of cognition.

The origin of the discipline of IT to a large extent explains the fact that it has not as yet coalesced around as clear a set of research questions as the other computing disciplines. Benbasat and Zmud (2003), refining work by Aldrich (1999) on organizational identity, argue that for a discipline to establish its own recognized identity within an existing environment, it must resolve two issues, namely, a legitimacy issue and a learning issue. The legitimacy issue itself consists of two subissues, namely, sociopolitical legitimacy and cognitive legitimacy. Sociopolitical legitimacy is conferred on a discipline when it is recognized as a separate discipline by key stakeholders, including the general public, governmental agencies, and, in the case of academic disciplines, academic administrators. IT fairly quickly obtained sociopolitical legitimacy. For example, shortly after its emergence, the Computing Accreditation Commission of ABET, the lead organization for accrediting programs in computing in the United States, and increasingly elsewhere, invited the IT community to formulate its own set of accreditation criteria. IT was also included in the efforts by the ACM, the AIS, and the IEEE-CS to formulate model curricula for the different computing disciplines.

However, the same cannot be said for cognitive legitimacy. Cognitive legitimacy is conferred on a discipline if it is recognized by others within the academic community as addressing a set of questions that are not addressed by any other discipline (such as IS did when it emerged) or when it is recognized as addressing questions that are addressed by other disciplines in novel ways (such as cognitive science). IT has not achieved cognitive legitimacy as yet. For example, there are very few PhD programs in North America in IT in the narrow sense in which the term is used here and very few research-oriented journals that focus on IT as a discipline.
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However, an academic discipline is unlikely to achieve cognitive legitimacy until it can resolve the other issue highlighted by Benbasat and Zmud, namely, the learning issue. The learning issue essentially involves the community establishing a coherent set of issues to study and/or developing its own set of methodologies, theories, and concepts to approach these issues. The IT community appears to be aware of the importance of resolving the learning issue, and there are a number of papers that attempt to discuss what unique contribution the discipline of IT might make to research in computing and what an IT agenda might look like (e.g., Reichgelt, 2004; Ekstrom et al., 2006; Agresti, 2011).

Many of the papers attempting to resolve the learning issue for IT contrast the discipline with other computing disciplines, in particular the field of IS. This may reflect the fact that the field of IS, more so than the other computing disciplines, seems to periodically engage in the type of meta-level discussions that, to date, have characterized many of the research-oriented discussions in the IT community (see, e.g., Benbasat and Zmud, 2003; Myers et al., 2011). It may also reflect the fact that the field of IS is the discipline that is most closely related to IT. For example, the most recent model curriculum for IS states that IS programs sometimes go under the name “information technology” (Topi et al., 2010, p. 12).

Moreover, when trying to draw a contrast between IT and the other computing disciplines, authors tend to rely on information about undergraduate programs. For example, early in the emergence of IT as a new computing discipline, a number of studies compared undergraduate programs in computer science, IS, and IT (e.g., Hislop, 2003; Reichgelt et al., 2004; Lunt et al., 2005), both in an attempt to legitimize IT as a separate computing discipline and to show how it differed from the other computing disciplines. More recent attempts to draw a contrast between IT and the other computing disciplines (e.g., Agresti, 2011) have relied on the so-called overview volume. The overview volume was published by a combination of professional organizations in an effort to draw a contrast between the computing disciplines of computer engineering, computer science, IS, IT, and software engineering (JTFCC, 2005). One can, of course, argue as to whether the structure of undergraduate programs should be used in trying to contrast the research agendas of the discipline. In the absence of any other sources, this is as good a place to start as any.

Three themes emerge from these discussions, namely, the central role of what has been called the IT infrastructure, its deployment, and the use of integration in its creation.

4.3 Underlying Themes for the Discipline of IT

The first theme that is central to many of the discussions on how to resolve the learning issue for IT is that of the IT infrastructure. The term “IT infrastructure” is defined by van Bon et al. (2007, p. 338) as “all the hardware, software, networks, facilities etc., that are required to develop, test, deliver, monitor or support IT services.” It then goes on to define an IT service as a service that is based on the use of the IT [defined as the use of technology for the storage, communication, or processing information] and supporting the customer’s business processes. The IT infrastructure is a subset of the “IT artifact.” The latter has figured prominently in discussions on the nature of the field of IS and is defined by Benbasat and Zmud (2003) as “the application of IT to enable and support task(s) within a structure(s) that is itself embedded within a context(s).” While there have been calls for improved conceptualizations of the IT artifact (e.g., Orlikowski and Iacono, 2001), the term, as defined by Benbasat and Zmud, encompasses not only the IT infrastructure but also the tasks, the task structure, and the task context in which the IT infrastructure is used. While there is considerable debate within the IS community as to the centrality of this concept to the discipline, with, for example, Benbasat and Zmud (2003) arguing that it had to have a central place in defining the discipline, with others disagreeing (e.g., Alter, 2003; DeSanctis, 2003; Ives et al., 2004), there is little debate within the IT community that the IT infrastructure has to
play a central role in the discipline. For example, the IT model curriculum (Lunt et al., 2008) contains the following 13 knowledge areas:

1. Programming Fundamentals [PF]
2. Information Technology Fundamentals [ITF]
3. Information Management [IM] (covering essentially database management)
4. Human Computer Interaction [HCI]
5. Social and Professional Issues [SP]
6. Platform Technologies [PT] (covering essentially hardware)
7. Networking [N]
8. System Integration and Architecture [SIA]
9. Integrative Programming and Technologies [IPT]
10. Web Systems and Technologies [WEB]
11. Mathematics and Statistics for IT [MATH]
12. Information Assurance and Security [IAS]
13. System Administration and Maintenance [SAM]

If we ignore those knowledge areas that either cover basic material or focus on general education topics (PF, ITF, SP, MATH), five of the remaining nine (IM, PT, N, IPT, WEB) directly relate to the IT infrastructure.

Clearly, the field of IT is not the only computing discipline to cover portions of these knowledge areas. For example, computer engineering covers knowledge areas such as platform technologies and networking, while software engineering and computer science would both claim to cover information management, programming (PF and IPT in the IT model curriculum), web technologies, human computer interaction, and at least some aspects of networking. IM and HCI both have a central role in the IS discipline.

However, and here is where the second theme emerges, as Agresti (2011) points out, the way in which these topics are covered in IT differs significantly from the way in which they are covered in the other computing disciplines. Agresti argues that each of the major computing disciplines has a separate theme. Thus, computer science, in its purest form, focuses on the theory underlying computing and seeks to formulate the mathematical and logical foundations of computing. Computer engineering focuses on the hardware necessary to physically realize computation, while software engineering focuses on the development of particularly the applications to run on the hardware. IS's focus is on the use of IT (used in the broader sense) to create business value and to provide support to the organization. IT, finally, focuses on the deployment of the technologies and their integration with existing systems. Agresti summarizes his analysis as follows:

<table>
<thead>
<tr>
<th>Discipline</th>
<th>Focus</th>
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<tbody>
<tr>
<td>Computer Science</td>
<td>Theory</td>
</tr>
<tr>
<td>Computer Engineering</td>
<td>Hardware</td>
</tr>
<tr>
<td>Software Engineering</td>
<td>Development</td>
</tr>
<tr>
<td>Information Systems</td>
<td>Organizations</td>
</tr>
<tr>
<td>Information Technology</td>
<td>Deployment</td>
</tr>
</tbody>
</table>

The model curriculum for IT programs includes knowledge areas that are directly relevant to deployment, in particular SIA and SAM. One could also argue that the knowledge areas of IAS and HCI are related to the issue of the deployment of the IT infrastructure.

A third, closely related theme, in the IT literature is the theme of integration. There are two different ways in which this theme emerges.

The first is most directly related to the deployment theme and concerns the integration of the IT infrastructure into the organization, including users of the IT infrastructure. Clearly, this is very similar
to what the field of IS considers to be its primary domain of research, and there is a significant overlap between the two disciplines in this area. However, whereas IT tends to focus more on the individual users, as witnessed by the inclusion of HCI among the knowledge areas in its model curriculum, IS places a greater emphasis on broader organizational issues. This is not to say that IT completely ignores the organizational focus, or that IS ignores the individual user. Indeed, HCI is a thriving area of research within IS and, indeed, computer science. The difference is primarily one of emphasis. Going back to the Zmud and Benbasat definition of the IT artifact as “the application of IT to enable and support task(s) within a structure(s) that is itself embedded within a context(s),” one could argue that IT approaches the issue of HCI primarily by focusing on the application of IT to support tasks, while IS is also concerned about the organizational structures and the context in which these structures are embedded.

The second way in which the theme of integration emerges in the field of IT concerns the construction of the IT infrastructure. Whereas the fields of computer engineering and software engineering tend to focus on one element of the IT infrastructure, hardware and software, respectively, the field of IT is primarily concerned with how one can integrate existing components into a new IT infrastructure to the benefit of the organization. Ekstrom and Lunt (2003) argue that IT programs should not require students to develop a deep knowledge of how individual technology components are to be implemented. Rather, such programs should instill in their students a deep understanding of the interfaces between the component technologies. This sentiment is also reflected in the IT model curriculum, where the more advanced programming knowledge area is called “IPT.”

4.4 Formulating Research Questions for IT

Having distinguished IT from the other computing disciplines, a number of questions arise when it comes to the issue of research, namely,

1. Are there a series of research questions that are unique to the field of IT and that are not covered by any other computing discipline?
2. Are there areas that are currently “claimed” by one of the other computing disciplines that could be “claimed” by IT?
3. For those research questions for which there is a significant overlap with other disciplines, is there a unique approach that IT brings and that is likely to uncover insights that are not provided by the other computing disciplines?

The questions in some way parallel the three strategies that Agresti (2011) suggests the IT community may follow in formulating a research agenda.

Agresti’s first proposed strategy is to seize on “judicial vacancies,” i.e., to lay claim on research questions that were never considered by other disciplines, or that are used to be but are no longer considered by another discipline. Clearly, this strategy parallels our first and third questions.

Agresti’s second proposed strategy is to build a research agenda by looking at current practice and abstracting frameworks and theories from these. This particular strategy would align well with the research that is done by many IT practitioners often resulting in white papers and case studies. Whereas such material often provides valuable insights into practice, there are few attempts to extract insights from these that are widely applicable and even fewer attempts to empirically or otherwise validate the more general conclusions from these studies. Agresti’s suggestion of building theoretical frameworks from practice parallels our third question. We return to this point in the next section.

Agresti’s third strategy is to establish a stronger tie with a reference discipline. Agresti argues that one of the reasons for the cognitive legitimacy of some of the other computing disciplines is their strong tie to well-established reference disciplines. Thus, computer science has as its reference discipline mathematics and derives some of its cognitive legitimacy from this link. Agresti argues that IT would do well to strengthen its tie with a well-established reference discipline and suggests that it looks to systems science (Bailey, 2005) as its reference discipline.
It is of course debatable whether systems science is as appropriate a reference discipline for IT as, say, mathematics is for computer science, primarily because the discipline is not yet as widely established. However, the general notion that IT looks at insights coming out of systems science and systems engineering does seem appropriate.

4.5 Research Questions Emanating from the Underlying Themes for IT

Given the absence of a well-established research tradition in IT, many of the answers to the three questions posed on the previous section are likely not to be unanimously agreed to by the IT community. In many ways, this chapter is, therefore, more intended as a catalyst for further discussion on IT research both within the IT community and within the larger computing research community. However, given the themes of the central role of the IT infrastructure, its deployment, and the use of integration in its creation, we can start formulating some tentative answers.

The use of integration in the creation of the IT infrastructure in particular is likely to lead to a series of research questions that are unique to IT. The following examples, in particular, are relevant:

First, is it possible to develop a framework to predict some of the emergent properties of the IT infrastructure, based on the value of that property in the components that were integrated and the way in which they were integrated to create the IT infrastructure? For example, given some value of the level of security provided by each of the components integrated into a particular IT infrastructure and the methods used to integrate them, is it possible to make some predictions about the level of security provided by the resulting system? One can ask similar questions, of course, about availability, cost of ownership, and so on. Moreover, those questions can also be asked about more dynamic system performance-related issues, such as throughput and power consumption.

The framework question also allows one to draw a cleaner distinction between the questions one might pursue as an IT researcher and related questions one might ask as a researcher in a different computing discipline. For example, computer scientists and computer engineers, in particular network engineers, are likely to be able to provide measures of security, availability, etc., as far as individual components are concerned. Thus, a computer scientist or software engineer will be able to answer questions about how vulnerable a particular software application is to malicious attacks, while a computer engineer may be able to answer questions about how easy it is to hack into network traffic on a particular type of network. Similarly, an IS researcher is very likely to be able to answer questions about the integration of the IT infrastructure into the organization and what factors need to be taken into account to ensure that security risks are minimized. However, the emphasis on the IT infrastructure itself is unique to IT.

Clearly, once developed, the framework should also have the ability to predict how the integration of a new component into an existing IT infrastructure is likely to affect the properties of the overall infrastructure. How will security be affected by the integration of some cloud-based service into the IT infrastructure? What effect will it have on availability, access, reliability, etc. Again, what sets IT apart in this respect from, in particular, IS is the emphasis on the IT infrastructure. The field of IS has interesting insights to offer on how the introduction of a new aspect may affect organizational performance, but its focus is exclusively on the organization and on the individuals within it. It does not concern itself with the IT infrastructure as an entity in its own right.

A second related question concerns issues to do with trade-offs between different aspects of the IT infrastructure. For example, it is possible to provide top-quality user support by making available a personal assistant to every user of the IT infrastructure, but clearly this is not feasible from a financial point of view. Similarly, it is possible to fully secure the IT infrastructure by denying access to any user, but this also is impractical. The question that follows from this is whether it is possible to arrive at a high-level framework for determining the optimum point on various trade-offs. For example, what is
the most appropriate point on the security–availability trade-off, what factors determine the appropriate point on this trade-off, and how are these factors weighted in a given organization?

Again, the question about trade-offs is not unique to IT. For example, the space–time trade-off is a well-known principle in computer science and computer engineering. Similarly, concerns about the cost/benefits trade-offs of IT applications underlie IT business value analysis, a subfield of IS. The main question of IT business value analysis is how IT impacts organizational performance of firms both at the intermediate process level and at the organizational level, and both in terms of (internal) efficiency and (external) in terms of competitiveness (Melville et al., 2004).

Similar concerns about trade-offs between costs and otherwise desirable properties of software applications, such as maintainability and loose coupling, also underlie Boehm and Sullivan's proposal that software engineering research pay greater attention to software economics (Boehm and Sullivan, 2000). Software economics proposes to bring economic reasoning about product, process, program, portfolio, and policy issues to software design and engineering. There is an obvious similarity here with IT in that one part of the IT research agenda is aimed at bringing reasoning about processor, process, program, portfolio and policy issues to the creation, implementation, and management of the IT infrastructure.

However, IT again brings a unique perspective on questions related to trade-offs and significantly broadens these concerns. The trade-offs considered in IT concern all aspects of the IT infrastructure and, as a result, concern a larger number of trade-offs than those considered in other disciplines. Thus, computer science and computer engineering restrict themselves to the space–time trade-off, whereas IT business value and software economics tend to concentrate on the trade-off between certain aspects of the IT infrastructure and value, where value is typically defined in financial terms. While the financial and organizational aspects are relevant to IT as well, IT also considers more technical trade-offs between different properties of the IT infrastructure, including cost and value, security, availability, usability, and scalability.

There are also a series of research questions that follow from the theme of deployment of the IT infrastructure. Whereas other computing disciplines have contributions to make to questions related to the creation of components of the IT infrastructure and/or to questions related to the deployment within an organizational framework, IT uniquely considers deployment from a technical point of view.

The theme of deployment is most closely aligned with Agresti’s suggestion that IT attempts to build theoretical insights from practice. As we stated earlier, there is a lot of anecdotal evidence on the value of certain processes, procedures, and best practices in deploying (aspects) of an IT infrastructure, often in the form of case studies and white papers, and often published by IT practitioners. While this material is extremely valuable, the research reported in it often does not meet the standards of rigor that is expected in academic research. In addition, almost no attempt is made to generalize from these case studies. As a result, such studies are often rejected by academic researchers.

However, the fact that the research as it stands does not meet the standards set by the academic community does not mean that it should be dismissed out of hand. As an academic discipline, IT might try to take some of this anecdotal information and turn it into scientifically validated theories. For example, there are a large number of studies available from IT consulting firms demonstrating the usefulness of adopting best practices as documented in the IT Infrastructure Library (ITIL) to improve the quality of the IT service delivery. Such papers provide valuable insight into practice and a thorough analysis of such papers might lead to the type of insights regarding the IT infrastructure that are unlikely to be obtained by following the more traditional scientific methodologies adopted by the other computing disciplines, in particular IS, which involve formulating a hypothesis based on a more widely adopted theory and testing that hypothesis. One can, of course, create similar research projects also around other IT best practice frameworks, such as CoBIT.

A related deployment-related series of questions concerns the derivation of theoretical insights, including best practices, from anecdotal information about other deployment-related issues, including business continuity and virtualization and cloud computing. In all cases, the thrust would be from documented case studies to general insights.
The theme of deployment and integration of the IT infrastructure within a structure of tasks to be performed by an end user also provides another avenue for IT research. While the various issues identified earlier do not appear to have been researched in a more abstract way, there is a growing literature on the use of the IT infrastructure within a particular application domain. A good example is provided by the health care industry where there is a growing number of well-established and well-regarded scientific journals on the use of IT to support health care delivery, including, for example, the *BMC Medical Informatics and Decision Making*, *Journal of the American Medical Informatics Association*, and the *Journal of Biomedical Engineering and Computing*. Moreover, one often finds articles related to the deployment of the IT infrastructure in journals that appear to be more geared to health care providers. For example, there are a number of articles on the inappropriateness of the interfaces to many electronic health records in such journals as *Critical Care Medicine* (Ahmed et al., 2011), the *Journal of Oncology Practice* (Corrao et al., 2010), and *Current Oncology Reports* (Markman, 2011). Health care delivery is but one example. One can find similar examples for many other domains, including education, criminal justice, and the military.

However, just as there typically is no attempt to generalize from the case studies published by IT practitioners, there typically is no attempt to generalize the lessons learned about the IT infrastructure, its deployment, and the use of integration from one domain to another domain. For example, are the issues of information assurance and security and the consequences that it has for the design of the IT infrastructure that arise in the health sector significantly different from the way these issues arise in the field of education? If so, why; what specific features of these application domains lead to these differences? Again, the thrust would be from domain-specific insights to more general insights and theories.

### 4.6 Conclusion

The discipline of IT, uniquely among the computing disciplines, primarily emerged in reaction to workforce development needs, rather than as reaction to a need for finding answers to new research questions, or to a need to employ new research methodologies to existing questions. As a result, it has not yet developed the strong research tradition that the other computing disciplines have developed. Thus, there are very few PhD programs in IT, and there are no recognized avenues for publishing high-quality IT research.

However, the IT community is acutely aware of this need to address this issue. It knows that in order to obtain legitimacy in the academic community, it must solve the learning issue for the discipline and arrive at a set of the research questions and/or research methodologies that it can legitimately claim as its own. One can expect IT research to emerge organically, especially as the consensus within the community about what sets IT apart from the other computing disciplines. However, such organic growth will take time and will, in any case, be encouraged through a meta-level research discussion about what an IT research agenda might look like.

This chapter has argued that the unique nature of IT as focusing on the IT infrastructure, the use of integration in its creation, and its deployment raises a series of questions to which IT can bring a unique focus. It has also argued that a practice-driven formulation of theories provides a unique methodological approach. The hope is that the points made in this chapter will help fertilize and expedite the organic growth of IT research that the IT community is so keenly looking forward to.

### References


