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Design Science II: The Impact of Design Science on E-Commerce Research and Practice

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ABSTRACT

With the promises of e-commerce come problems and opportunities for researchers and practitioners. One of these opportunities is taking a design science approach to e-commerce research. The argument is made that design science makes a contribution of theory in business school research. Contributions of design science to the research and practice of e-commerce are categorized into artifacts that aid e-commerce practitioners, artifacts that aid e-commerce researchers, and theories related to these artifacts. However, the design science approach introduces limitations such as the perishability of design science artifacts, and the time it takes to develop an artifact to the point where it is useful for practice.

Keywords: Design science, contribution of theory, e-commerce, artifact, Internet agent, systems development methodology

I. INTRODUCTION

The excitement about e-commerce for both practitioners and researchers is the result of technologies that promise to add significant value to the firms that adopt them. Much of this excitement is not concerned with what already happened; but with what is expected to happen in the future. Traditionally business researchers waited until new technologies were created and

implemented before they tested how the technologies impacted commerce. Although valuable insights are provided to practice from this traditional approach, such research does not ameliorate the risks of developing e-commerce applications. These risks are borne by pioneering businesses that are first to design and implement a new e-commerce technology.

Even though first mover advantage can be beneficial for a business, often a pioneering firm incurs a great cost in developing and implementing a new technology. Once a technology is proven valuable for a firm, it can often be replicated and improved upon by the firm's competitors at a fraction of the cost incurred by the pioneering firm. The first mover's competitive advantage is quickly eroded. In addition, the pioneering firm faces the risk that the technology it develops will not actually solve the problem that it was intended to solve. A failed project represents a cost to the pioneering firm that cannot be recovered. This risk represents a problem for the firms participating in e-commerce.

Business research must be relevant to practice [Benbasat and Zmud 1999]. Researchers ensure that their work is relevant to practice by studying issues that practitioners face. Business school researchers have an opportunity to help mitigate the risks faced by e-commerce practitioners by focusing effort on the risk outlined in the previous paragraph. Problems faced by practitioners in developing e-commerce applications are properly studied from a design science perspective [Au 2001][1].

The design science approach also can solve problems inherent in traditional e-commerce research. For example, gathering data in e-commerce domains can be a daunting task. Because it is possible to gather large amounts of information about a phenomenon, the expectations for traditional quality research were raised to include the analysis of large amounts of data. Design science offers new methods for conducting research that can substantially aid

[1] Design science activities may lead to artifacts that are marketable by the researcher. Although this paper makes the point that researchers should solve the problems of practice, I do not wish to imply that researchers should not be able to profit from their research. Even when researchers (or the universities that employ the researcher) patent the results of a research project, this does not diminish the fact that an advance has been made that benefits practice.

the traditional researcher in e-commerce research (Section IV). Among these methods is the development of intelligent software agents [Kauffman, et.al., 2000] which promise to facilitate data collection and analysis where traditional methods would prove to be ill-suited.

II. DESIGN SCIENCE AND BUSINESS SCHOOL RESEARCH

March and Smith [1995] define design science as those activities that a researcher participates in to "create things that serve human purposes". The "things" that are created are often described as artifacts. March and Smith further argue that design science leads to four types of outputs:

- constructs,
- models,
- methods and
- implementations.

Constructs and models are descriptive in nature. They describe the artifact, often describing the relationship of the artifact to its environment. Methods and implementations are prescriptive. Methods explain how an artifact ought to be developed, while implementations are the artifacts. Design science can be particularly valuable since the goal of design science is to create artifacts that effectively solve the problems humans encounter. Fields that attempt to prescribe action to practitioners tend to exhibit some form of design science.

The role of design science in academic research in business schools is a subject of controversy. Information systems (IS) research includes at least two distinct camps, each with a different view of the appropriateness of design science research. Those who advocate design science as viable research argue that the design of artifacts with its underlying theory can be as important a contribution to knowledge as good behavioral or economic research. Some researchers in IS argue as Ron Weber [Weber, 1987] that design science offers IS a much-needed paradigm, carving out a niche for that discipline of research.

Those who argue that design science is not quality research believe that the design of artifacts does not make a significant enough contribution and is therefore not appropriate for the business school researcher. March et al. point out that critics of design science cite the lack of papers by design scientists in three of the most prestigious research outlets in the discipline (*MIS Quarterly*, *Information Systems Research*, and *Journal of Management Information Systems*) [March, et. al., 1999] as evidence that design science is not valued by the main stream of IS research.

In addition, opponents of design science in the business school argue that design science is best performed by research companies (such as SRI International and Rand) that are able to devote full-time, experienced researchers to transforming theory to practice. Faculty researchers are not able to devote all of their efforts to research activities because of teaching and service constraints; while relatively inexperienced researchers (PhD students) often take prominent roles in research projects. Although I agree that research companies are well equipped for the transfer of theory to practice, their capabilities do not dismiss the role design science should play in the University. Universities also have a distinctive competency for doing research [Wetherbe, 2001]. Since university researchers are qualified to conduct design science research, they should not be disqualified from conducting that research because they are unable to devote all of their efforts to the work. The judicious use of teams of faculty and PhD students can compensate.

Not surprisingly, design science researchers often find it difficult to justify their research to tenure committees. Ironically, design science activities lead to the production of inventions that can provide a source of revenue for the school. Many universities own the patent rights for any artifacts that are developed as a result of the research efforts of the professors they employ. For example, as of 1999,The University of Minnesota held patents for 362 inventions that resulted in income ranging from $1000 to $7 million [University of Minnesota 1999]. Those schools that discourage design science activities might very well be forfeiting the revenues design science activities could bring.

Although this article will not conclude the design science debate, it asserts that design science is a viable mode of research, which has a significant contribution to make in the study and practice of e-commerce. These assertions are based on two key criteria for business school research:

- The research provide a contribution to existing thought, and
- The research is publishable.

WHAT'S IN A THEORETICAL CONTRIBUTION?

Whetten [1989], when he was the editor of the prestigious *Academy of Management Review*, addressed the question of what constitutes a theoretical contribution in business research. He argued that research contributions can be categorized as either:

- a contribution *to* theory, or
- a contribution *of* theory.

To Whetten a contribution *to* theory is characterized as taking an existing theory and adding some insight to the theory to make it marginally more complete. He believes that such a contribution to theory typically does not merit a place in the academic world's most prestigious journals. A contribution *of* theory, on the other hand, does more than just alter existing thought; the researcher modifies or expands existing theory in important ways.

A contribution *of* theory must also explain some key components of the phenomena under study. At a minimum, a theory must explain the *what, how,* and *why* of the phenomena. It must also define the *who, where* and *when* of the theory. What and how describe the phenomena by defining the agents that are studied and how these agents interact. They are purely descriptive and rarely constitute a contribution without the added power of explaining why. Why is the essence of theory because it postulates an explanation for the events that are studied. Describing the what, how, and why of a phenomenon are key to creating a contribution to theory. Who, when and where are necessary because they define the boundaries of the theory. Table 1 defines each of the criteria and explains how design science satisfies each of them.

Table 1. Design Science and Whetten's Criteria for Contribution of Theory

Criteria	Explanation of the Criteria	How Design Science Fits the Criteria
What	Which factors (variables, constructs, concepts) are involved?	The factors studied are the artifacts created by the scientist as well as the effects an artifact has in its sphere of influence.
How	How are these factors related?	The artifact is designed to solve a particular problem, the how is answered when the artifact is evaluated to ensure it solves that particular problem.
Why	What underlying logic justifies the selection of the factors and proposed relationships?	This is satisfied when the design scientist uses or creates sound theory that guides the design of the artifact. This must be evident in good design science research.
Who, Where, When	Sets the boundary conditions of the theory.	The limitations of the artifact as well as the boundaries of the theory must be defined by the researcher.

THE PUBLISHABILITY OF DESIGN SCIENCE RESEARCH

Whetten also provides key criteria for evaluating a contribution *of* theory in terms of its publishability in *The Academy of Management Review*. These criteria could also be applied appropriately to work submitted to other quality management journals. He argues that every proposed contribution of theory must address six key issues to be considered for publication.

These issues are: *what's new, so what, why so, well done, done well,* and *why now*. These criteria are described in Table 2. They serve as a benchmark for the publishable quality of a work.

Design science research provides a contribution of theory that satisfies the criteria for publishability in top business journals[2]. Clearly, if design science can pass the strict criteria for making a contribution of theory, as well as the criteria for publication in the most rigorous journals, it qualifies as an appropriate method for conducting research in the business school. The debate really should not be

[2] Most journals have a particular focus that may or may not fit well with design science work. Although this may be the case, I argue that focus is separate from quality. Good design science research can reach the same quality as traditional research and therefore is of the same merit as traditional research.

Table 2. Whetten's Criteria for the Publishability of a Theory

Criterion	Explanation of the Criterion	How Design Science Fits the Criteria
What's New	What is it about this work that adds to the existing body of knowledge?	A new artifact is created that becomes the object of study.
So What	What will be the impact of the research findings on a particular area of practice and what will the scope of this impact be?	The new artifact must be validated to demonstrate superiority over past approaches.
Why So	Are the logic and support for the theory or arguments that are made valid?	A theory to explain the superiority of the artifact is developed.
Well Done	Does the work represent thorough and complete thinking? Does it represent well rounded and deep thought?	Demonstrating that the artifact does indeed solve a particular problem completely and thoroughly.
Done Well	Does the work represent good work and scholarship? Does it reflect a high level of quality?	Demonstrating that the artifact and associated theory are constructed in a quality fashion.
Why Now	Is the question relevant to the current work being done? Is the research timely?	Artifacts should arise out of a perceived need of stakeholders which leads to relevance.

about whether design science is appropriate for business research, but rather about what types of business problems are most suited for a design science approach.

III. HOW DESIGN SCIENCE FITS E-COMMERCE PROBLEMS

E-commerce is an emerging field for both practitioners and researchers. Practitioners endeavor to create and implement technologies that shape e-commerce. Researchers endeavor to understand new markets and business opportunities while at the same time explain to practitioners how to exploit these opportunities. Design science can offer practitioners and researchers valuable solutions to e-commerce problems. These contributions are likely to come in the three forms shown in Figure 1.

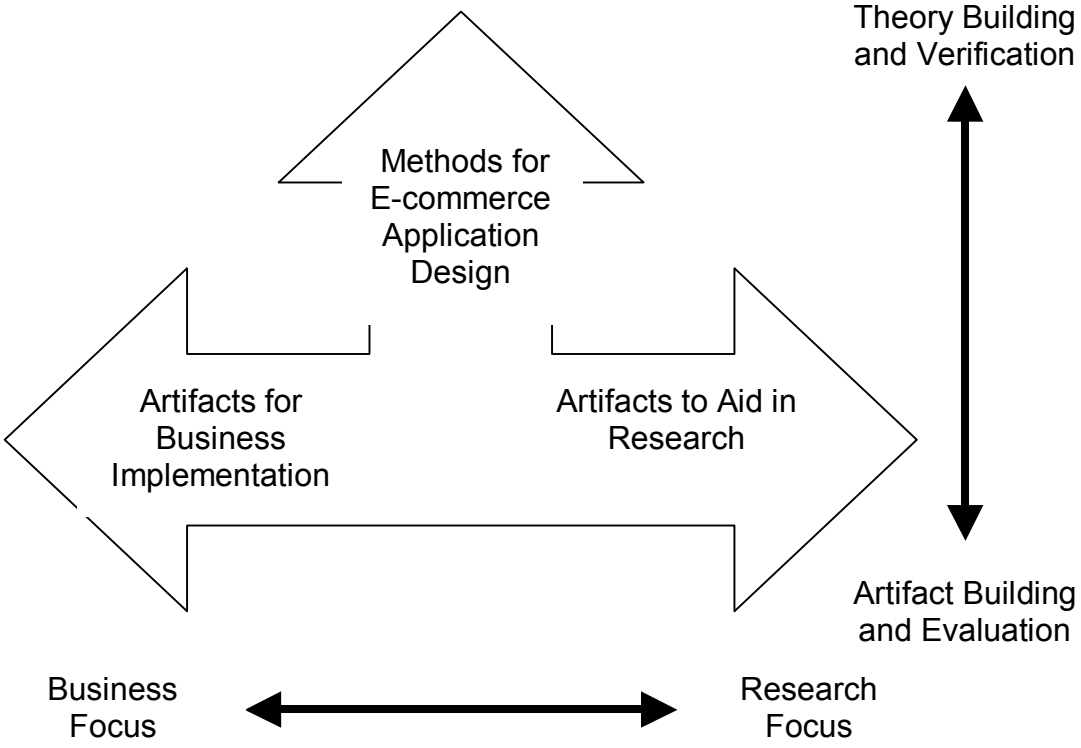

Figure 1. The Impact of Design Science on E-Commerce

Design science can lead to the building of artifacts for implementation (or at least examples of types of applications that can be implemented) directly in business. Design science can also lead to building artifacts that aid in research about e-commerce. In addition, design science can lead to the development of methods that guide how e-commerce applications should be built.

March and Smith [1995] argue that basically four activities are involved in research (Table 3):

(1) building artifacts, (2) evaluating artifacts,
(3) building theory and (4) verifying theory.

Table 3. The Contributions of Design Science to E-Commerce

Design Science Activity	E-Commerce Problem Solved
Building of Artifact - based on a perceived need or void in existing technologies	Presents practice with at least a prototype of a solution to a technology problem.
Evaluation of Artifacts – usually done in tandem with the building of artifacts, but could be done for existing artifacts.	Determines whether the artifact solves the problem it was intended to solve.
Theory Building - to explain why one approach to solving a technological problem is superior to another	Presents an explanation for why one approach to solving the problem is better than another - this ability is particularly valuable for applying a theoretical approach to several different problems.
Theory Testing - to verify theories that have been developed.	Provides evidence that one approach is better than another. This evidence aids in determining the extent to which one approach is likely to help solve a problem.

Each of these activities constitutes a research contribution. The four activities can be grouped into two related categories:

- building of the artifact and
- the theory underlying the artifact.

Although I would argue that all four of these elements must be present to some degree in design science research before the results of a project become a significant contribution, it seems clear that different forms of design science research are likely to demonstrate some of these activities more than others.

The development of methods for building e-commerce applications will tend to rely on theory building and verification more heavily than building artifacts. Theory represents the vertical dimension in Figure 1. The researcher who focuses on the building of artifacts will rely less on the building and verification of theory and vice versa.

Whetten, as well as Benbasat and Zmud (1999), argue that research in a practical field, such as business, must be relevant to the field's stakeholders. The researcher who tackles only those problems that are of personal interest

risks making his work irrelevant, or out of touch with the practitioners he is trying to work with. Developing artifacts grounds the research in the problems faced by the stakeholders of the research. As design science research moves toward the left of Figure 1 (i.e., more toward the building of artifacts for business), the research is both grounded in and focused on the needs of practitioners. In the other direction (toward building artifacts to aid research), the focus shifts toward the needs of researchers in studying e-commerce, but is likewise focused on and grounded in the problems faced by researchers. In summary, design science research is grounded, practical research.

BUILDING ARTIFACTS FOR BUSINESS

Design science is well suited for e-commerce research because there are so many areas of e-commerce are yet to be explored. Examples of e-commerce issues that could profit from research are cultural differences in customer preferences in e-commerce sites, improving techniques for converting customers who browse e-commerce sites to customers that purchase from those sites, and understanding how the design of websites affects the purchase decision. Ideally, design scientists should work with practitioners to determine where advances in technology are needed. The design scientist helps to create artifacts to fill these needs and then evaluates the artifacts to determine whether the initial need is met. Theories can also be built to determine if this artifact is a superior solution to the problem. Finally, these theories are verified to make certain that they contribute to both scientific and practical knowledge.

The previous paragraph describes the design science research cycle, from artifact development to theory verification. Often the different components of the life cycle are completed at different points in time. For example, a research project may develop and evaluate an artifact to ensure that it solves the problem it was intended to solve. At this point the artifact (or variants of it) might be implemented into practice. The theory development and verification stages of the research cycle might be conducted for years after the artifact has been utilized by practice. Each of the component parts of the cycle can offer valuable

contributions to practitioners, even though all of the components are rarely delivered at the same time. Artifacts provide working examples of applications that may prove to be beneficial. Theory provides laws and principles upon which sound applications are built. Because each of the parts of the design science research cycle are valuable; design science can offer timely solutions to practice, though years may elapse between the development of an artifact and the verification of theory related to it.

DEVELOPING METHODS FOR BUILDING E-COMMERCE APPLICATIONS

Design science can offer more than just theories about the types of applications that can be built to serve e-commerce. It can also provide a method for developing e-commerce applications. E-commerce applications differ fundamentally from other business applications because they serve a different user population. In the past, IS applications were used only by company employees. Although significant efforts were made to develop design methods that take account of the needs of the employee-users of the systems, these efforts are incomplete when it comes to designing e-commerce applications. For example, the users of an e-commerce application are external to the firm, typically its customers or suppliers. Whereas employees were required to use an information system as part of their job, customers are able to choose which applications they will use. If a customer chooses not to use the e-commerce application of a specific firm, he or she may well choose to transact with a different firm that provides a better e-commerce application.

Current research on application development describes what is known as the systems development life cycle. The typical systems development life cycle describes the stages of successful project development. The stages of the development life cycle are analysis, design, construction and implementation [Kendall and Kendall 1993; Plyley and Young-Gul 1993; Necco, et. al. 1987].

A DESIGN SCIENCE EXAMPLE – INFORMATION CUSTOMIZATION

The research by Gediminas Adomavicius, a computer science doctoral student, and Alexander Tuzhilin, an IS faculty member in the Stern School of Business [Adomavicius and Tuzhilin, 2001] is an example of design science research in an e-commerce setting. They study the need for companies to customize the information customers see when they access company websites on the Internet. Such customization is believed to lead to greater profits for the company because information can be targeted specifically to the customer and his or her likely preferences. They argue that existing technologies for determining what information to show customers are limited in their effectiveness. They designed and built a new mechanism, or approach, for determining user preferences. Although their prototype will likely not be developed to a point that a company can implement it directly, the underlying theory they use to build the artifact can guide the production of similar applications created by firms.

Although these steps provide a nice blueprint for generic systems design, it is incomplete for many aspects of e-commerce application development. Design science researchers can develop methods to aid practitioners in the development of e-commerce applications. Examples of areas of system design that can benefit from future research are determining customer needs (as opposed to user specifications) in the analysis phase and speeding the development of e-commerce applications. When used in tandem with current methods, these more specific methods would provide a mechanism for practitioners to develop successful e-commerce applications. This type of design science research would likely be much more concerned with the building and verification of theory rather than the building and evaluating of artifacts.

THE BUILDING OF ARTIFACTS FOR CONDUCTING E-COMMERCE RESEARCH

Design science also offers benefits to traditional researchers. In the course of conducting research on e-commerce, a researcher is not only able to capture a sample of the phenomenon of study, she is also potentially able to capture the entire population. To obtain a 100% sample, the researcher must have methods for gathering and categorizing large amounts of data. Many pieces of data must be captured 24 hours a day. This task is daunting for an individual or even a team of researchers. To solve this problem, researchers develop Internet agents (i.e., artifacts), to capture and categorize data [Kauffman et al., 2000].

Internet agents provide a powerful research method. The method can be superior to traditional data collection techniques for much of e-commerce research for the following reasons.

- Internet agents can constantly monitor the phenomenon under consideration, capturing important pieces of information without user intervention. That is, agents gather real-time data.
- Internet agents are impartial, collecting the data they are programmed to obtain without bias. Internet agents are free from clerical error.
- Internet agents collect data without influencing the objects being studied.

Table 4 summarizes the use of agents as a research method.

Traditional data collection methods require the researcher (or a research associate) to be present whenever real-time data is gathered. Traditional data collection personnel can be biased, even if only subconsciously, during the data collection process; thereby imposing value judgments about the data collected [Connor and Becker 1977]. Traditional collection methods are subject to both systematic and random measurement error, including clerical mistakes in the recording of data [Thye 2000, McGrath 1992]. Data collection personnel may also influence the subjects of the experiment without intending to, biasing the

Table 4. Internet Agents As a Research Method

Problem In Electronic Commerce Research	Explanation of Problem	How Design Science Can Solve the Problem
Need for Constant Collection of Data	Electronic commerce data often needs to be collected 24 hours a day to obtain data in real time	Internet agents work without supervision 24 hours a day.
Potential bias in collecting data	This problem is not new for electronic commerce research. Those hired to collect data may be biased about what data is important to capture.	Although proper techniques eliminate this bias in traditional methods, agents make no value judgment about data collected.
Clerical Error	This problem is not new for electronic commerce research. Those hired to collect data may be prone to clerical error.	Although proper techniques eliminate clerical errors in traditional methods, agents make no clerical errors.
Potential manipulation of environment by researcher	The researcher rarely desires to influence the outcome of the study by influencing the agents studied	Collection agents are able to capture data without manipulating the actions of the agents involved.

data collected [Connor and Becker 1977]. Although these sources of error cannot be eradicated completely, using technological artifacts to collect the data can eliminate some of them.

The development of Internet agents is an example of design science as a method for conducting research. The design researcher can develop an artifact that is capable of conducting the research. Agents are able to, without supervision, mine specified Internet sites for information relevant to a research project. An example of an effective Internet agent can be found in the discussion of E-DRILL in the sidebar below. The development of Internet agents often makes it possible to study phenomena that would otherwise be impossible capture. In truth, the design and maintenance of Internet agents used in research can be a difficult task. The eventual goal of intelligent research agents is an application that can adapt to many different websites to search for relevant data without requiring any additional instructions from the user. The reality of current research applications is that the agent must be modified for each unique

A DESIGN SCIENCE EXAMPLE – E-DRILL

Kauffman, March, and Wood discuss several considerations in developing intelligent agents for collecting data from Internet sites [2000]. As an illustration, they discuss a specific agent, E-Drill, which was used to collect data from E-Bay, a popular Internet auction site. E-bay hosts auctions for several different types of products. Each product group has a unique identifier so that common products are grouped together. E-Drill is designed with a user interface that allows the user to input a unique identifier for the type of products about which the user wants to gather information. The user is also able to enter search terms that further narrow the search. Once the search parameters are determined, the agent "drills" E-Bay for each of the items for sale. Once the items are found, E-Drill parses through all of the information about the item. Relevant information about the bidders and bid amounts are stored in a database for future analysis. To demonstrate the capabilities of E-Drill, data were collected about rare coins on auction. Once the original parameters were set, E-DRILL collected information about 49021 unique bids on over 12000 items.

website it mines. The costs and benefits of developing and maintaining these agents must be balanced with the costs and benefits of more traditional data collection methods, so that the researcher uses the most appropriate method. Advances in the intelligent agent technology will greatly benefit researchers that use agents for conducting research. In this sense, design science efforts in developing artifacts for conducting research are also scientific contributions.

IV. LIMITATIONS OF THE DESIGN SCIENCE APPROACH

The reader should be aware of the limitations to the design science approach. Most of the limitations revolve around the availability of resources for building artifacts. These limitations govern the extent to which an artifact can make a significant contribution.

One prominent limitation is that the technologies used to build artifacts are perishable. By the time a researcher is able to develop an artifact to the point that it is ready for implementation in practice, the technology used in the artifact might be obsolete. The extent to which the contribution that is developed is grounded in the technology used to build the artifact, the weaker it will be. Instead, it must be grounded in the problem that the artifact was designed to solve and in explaining why the approach used to build the artifact solves the problem more effectively than another approach. Contributions that are based solely on the technology of the artifact are as perishable as the technology itself.

It is often impossible for a single researcher to develop an artifact to a point that it is usable by businesses in a practical way. Academic researchers, working alone, can often only create a prototype. This limits the ability to verify that the artifact is in fact a solution to the problem. With this in mind, the researcher should always have the theory foremost in his research efforts and look for opportunities to demonstrate the utility of this theory in solving the problems faced by practitioners. The process (or theory) used to solve the problem is the valuable scientific contribution, because it can be applied to new settings even after the technology of the artifact becomes obsolete. In addition, effective design science research may require the use of research teams. Section III points out that the components of design science research are often completed at different times. Furthermore, different researchers can complete the different components of design science research. For example one research effort could revolve around the building and evaluating of the artifact while another focuses on building theory related to the artifact. These two research efforts might appropriately have different sponsors.

Design science can be profitably done with researchers working in tandem on the same research effort. Although this model is not well established in business research; other fields, such as engineering, provide strong examples of team research. At the core of limitations to design science research is the problem of obtaining adequate resources (be they monetary or human capital). Resources affect the time it takes to bring a design science project to the point

where it is useful for practice. Using a team approach can provide the additional resources to complete a project that would otherwise prove to be unmanageable for any single researcher.

V. CONCLUSION

The debate over the proper role design science should play in IS research has been raging for many years. This paper discusses why the design science approach can make a theoretical contribution to existing business research. It also discusses why design science is properly positioned to offer solutions to implementation problems faced by both practitioners and traditional researchers in e-commerce. In addition, it cautions those who engage in design science research on the limitations of the contributions that can be made.

It should be noted that although the comments made in this paper are primarily concerned with the impact of design science on e-commerce, the impact of design science has a much broader scope. The relationship between e-commerce and design science was singled out to highlight an emerging area of research that can benefit greatly from the design science approach. Just as design science will provide valuable artifacts and theory to e-commerce research and practice, it will prove to be a powerful tool for attacking many other business problems.

To those that feel there is no place for design science in business research, this article will likely do little to change their minds. To those who are honestly looking for good methods for attacking the problem of e-commerce practice and research, this article provides insights into why design science is an appropriate tool.

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