The Research Pyramid: A Framework for Accounting Information Systems Research

by

Julie Smith David*, Cheryl L. Dunn**, William E. McCarthy***

& Robin S. Poston***

*Arizona State University

** Florida State University

***Michigan State University

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Abstract

This paper extends Sowa's Meaning Triangle (1997) to develop a framework for accounting information systems (AIS) research – the Research Pyramid. This framework identifies relationships between *objects* in economic reality, people's *concepts* of economic reality, *symbols* used to record and represent economic reality, and the resultant *accounting information systems* that capture and present data about economic reality. The Research Pyramid has two major uses. First, the paper illustrates how the Research Pyramid can be used to identify new research questions to extend existing research streams. To be used in this manner, existing AIS research is classified along each of the edges of the Research Pyramid. Once an area of the literature has been analyzed, the edges that have not been studied extensively reveal potential primitive mappings for future exploration. Second, each primitive mapping is evaluated to identify which of four research methodologies (design science, field studies, survey research, and laboratory experiments) are likely techniques for use in future studies. This analysis can help researchers with strong methodological training to identify new, interesting questions to be answered that capitalize on their research strengths. As such, the Research Pyramid is a tool to characterize existing AIS research, identify areas for future exploration, and provide guidance on appropriate methodologies to apply.

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I. Introduction

To date, accounting information systems (AIS) research has not matured to the point of having a framework to describe its research areas nor the major constructs under investigation. As a result, it is difficult to identify areas for future research and relationships between research streams. This article develops such a framework based upon an expansion and re-interpretation of Sowa's (1997) Meaning Triangle. The framework identifies relationships between *objects* in economic reality, people's *concepts* of economic reality, *symbols* used to record and represent economic reality, and the resultant *AIS* that capture and present data about economic reality. Each relationship can be used to identify AIS research questions that further the understanding of the role of AIS in today's business organizations. Further, each relationship is evaluated to determine methodologies that may be most appropriate for future research.

The remainder of this paper is structured as follows. Section II defines AIS for purposes of the framework discussion, and section III introduces the proposed research framework: the Research Pyramid. Section IV presents an overview of four methodologies that have been used in AIS research. Section V identifies potential research questions resulting from each primitive mapping of the Research Pyramid and assesses the applicability of the four methodologies for studying these questions. Section VI illustrates how the Research Pyramid can be used to identify research opportunities within a stream of AIS research, and section VII concludes the paper.

II. AIS Definition

Defining AIS has been difficult to date, and research in the area is quite diverse. It includes behavioral studies of audit decision-making tools, field studies of organizational systems, design and development of general ledger systems, design and development of accounting models that effectively utilize advancements in computer technology, application of different technology solutions to AIS classroom situations, and many other types of studies. While all of these research ventures add to academic knowledge, it is difficult to explain what AIS is to colleagues in accounting and in other areas of business education. Providing a definition of AIS can help us better focus future research efforts.

In general, an information system is used to represent real world phenomena with a set of symbols that are themselves captured and implemented within a computerized environment (McCarthy 1979). Therefore, that an *accounting* information system is one that translates representations of economic activities into a format that is valuable to accountants and to their customers -- i.e., business decision makers -- who need information about economic activities. Accountants are being pressured to re-define their contribution to organizations and to expand the scope of their activities beyond financial statement preparation and analysis (Elliott 1994, Brecht and Martin 1996). They are being called upon to become active enterprise-wide team members who provide information and guidance in strategic decision-making situations. Similarly, day-to-day operations managers demand a wide range of financial and non-financial performance measures. Therefore, if an AIS is going to allow today's accountants to provide the information business decision makers need, it should meet the following definition:

"An accounting information system is one that captures, stores, manipulates, and presents data about an organization's value-adding activities to aid decision makers in planning, monitoring, and controlling the organization[1]."

This definition certainly includes financial accounting systems, which have the primary purpose of generating financial statements in accordance with Generally Accepted Accounting Principles. However, this definition recognizes that businesses must perform a wide range of value-adding activities (such as production, distribution, sales, etc.) to be successful, and that the types of information needed to manage such activities will be extensive. Therefore, the scope of corporate systems that are included under the AIS umbrella is much broader than the general ledger system and the programs that prepare journal entries to feed it. Rather, an AIS is a system that aids in processing transactions and in tracking the data that results from such transactions. These systems also must provide performance measurements (financial and non-financial) and help enforce management control objectives. They include transaction processing systems (such as billing systems for sales processes), interorganizational systems that share data with upstream and downstream partners (such as web-based order systems and electronic data interchange cash receipt processing), and support systems that enable economic exchanges (such as order processing, customer market analysis, and inventory control systems).

This definition has strong integrative implications. For example, the impact of enterprise resource planning (ERP) systems on the market has been dramatic. These systems were initially designed around core functions such as manufacturing or human resources. As they matured, their breadth expanded to include much more of the organization's activities. The key characteristic they embraced was developing an integrated data repository that was accessible by users throughout the organization. ERP systems provide massive amounts of data that is updated in real time, and they are able to provide greater planning support and a wider range of performance measurements than were previous manufacturing or management planning systems. Using the definition of AIS provided here, research on ERP systems would be characterized as falling under the AIS research umbrella.

III. A Framework for Identifying Important AIS Research Questions

Many important research questions can guide academic researchers and accountants as they develop an extended view of their information processing capabilities and responsibilities. Perhaps the most fundamental question that must be addressed is: *What are differentiating characteristics of competing AIS? Which provide the most value to organizations*? If these characteristics are identified, distinguishing which AIS better meet firms' goals is a valuable research question. To answer this inquiry, however, significant research is necessary to identify how to measure the value of an accounting information system. To spur future research in AIS, a broad research framework is presented to guide efforts to systematically study components of this research domain.

(insert Figure 1 approximately here)

As a first step in discussing AIS research opportunities, Figure 1 portrays a model of the reality abstraction and representation process (as adapted from McCarthy (1979), Sowa (1997), Haeckel and Nolan (1993), and Beedle and Appleton (1998)). The "Meaning Triangle" in the middle of the figure is from Sowa, and it illustrates that real world **objects** (such as those existing in the day-to-day operations of a company called "Sy's Fish") are (1) perceived as **concepts** in the minds of humans and (2) represented as **symbols** in linguistic, paper, or electronic form for communication with other humans. These symbol systems (as representations of perceived objects) can be implemented on computers in modern information systems.

Although Sowa's Meaning Triangle did not include information systems as a dimension, it is apparent that they are, in fact, related to each construct in the original model. By adding **accounting information systems** as another point in the Meaning Triangle, a Research Pyramid is created (see Figure 2) to guide research into how AIS interact with objects, concepts, and symbols. Specifically, AIS capture, store, manipulate, and present data that represents objects in the organizational reality. System designers create symbolic representations of organizational reality to create an AIS. Users typically provide system designers input based on their mental models, which in turn can be influenced by their interaction with the system in place.

(insert Figure 2 approximately here)

The constructs in this framework have been described in several research domains, although the specific terminology has varied between these fields. Table 1 shows ideas adapted from Sowa (1997), Haeckel and Nolan (1993), Beedle and Appleton (1998), and McCarthy (1979, 1982). Sources are used here to clarify these components of the Research Pyramid.

(insert Table 1 approximately here)

Objects in Physical Reality

Objects include entities that exist continually (*continuants*) or activities that occur in time (*occurrents*) in an enterprise's reality (Sowa 1997). Therefore people, things, and events are encompassed by the object construct. Objects exist in what Haeckel and Nolan (1993) refer to as physical space. Beedle and Appleton (1998) discuss networks of objects that exist or happen in reality as "patterns in the world." In a Resources Events Agents (REA) sense (McCarthy 1979, 1982), objects constitute the economic reality of an enterprise, and they include its economic resources, events, and agents.

Concepts

Sowa (1997) identifies a concept as a person's mental representation of an object or objects in physical reality. Haeckel and Nolan (1993) refer to the mapping from physical reality to a person's mental representation of that reality as a neural space map. Beedle and Appleton (1998) refer to networks of concepts as "patterns in our mind." McCarthy (1979, 1982) did not make any specific references to users' mental representations; in this paper the term "enterprise mindset" is used to describe how these phenomena would fit into his work.

Symbols

Symbols as used by Sowa (1997) in the Meaning Triangle are notational representations of physical reality. Haeckel and Nolan (1993) describe the mapping of a physical reality into a symbolic representation as a "semantic space map." Beedle and Appleton (1998) describe symbol networks as "patterns in the literary form." The symbols used in McCarthy's (1982) REA model combine to form an "enterprise information architecture." In total, the symbol construct as used in the Meaning Triangle represents the formalized design documentation of a physical reality. Such a symbol set can serve a wide variety of roles in AIS research projects.

Components of Accounting Information System

AIS refers to the components of an accounting information system, i.e., a specific system implementation. Haeckel and Nolan (1993) refer to the mapping between objects in physical reality and components of an information system as "implementation space." "Patterns in databases and programs" reflect implementation of symbol networks. McCarthy (1982) would refer to a company-wide AIS implementation as an enterprise information system.

IV. Overview of Research Methodologies in AIS

This section briefly reviews four research methodologies that have been used in AIS research: (1) design science, (2) field studies, (3) surveys, and (4) laboratory experiments. The basic uses for each methodology are discussed, along with their strengths and weaknesses. In a later section of the paper, these four methodologies are tied to the elements of the Research Pyramid described above.

Design Science

Design science techniques are used to perform normative studies in which the researcher evaluates theories of what types of systems *should* be developed or proofs that new system designs are feasible. These design science researchers often build computer systems as a way of discovering new phenomena and further exploring known phenomena (Newell and Simon 1976). Certainly, the most prominent strength of a design project is that it produces a tangible result that can be evaluated on its efficacy and efficiency as suggested by March and Smith (1995). However, there are significant costs associated with this methodology. First, and perhaps most important, this type of research requires significant time and effort to acquire an expert understanding of both the problem being addressed and the technologies available that may result in a solution. Additionally, it is difficult to evaluate most design projects using the statistical techniques that are prevalent in accounting research, so the design science researcher must rely on more heuristic guidance to control project quality (McCarthy, Denna, Gal, and Rockwell 1992).

The best preparation for design science work is to become intimately familiar with the problem being addressed and the plusses and minuses of the various prescriptions (or new IT solutions). The researcher must develop a strong intuitive feel for what a new improvement might add. This sounds very situation specific, and it is. However, it should be obvious that normative or design work in AIS must always proceed first from an understanding of the domain, not from availability of technology. In fact, some past design science research has been of poor quality because researchers applied new technologies to problems they had not fully analyzed. As a result, the academic contribution of such projects was limited (McCarthy et al. 1992; Sutton 1992).

Excellent primers for researchers interested in design approaches to AIS research problems are the 1995 paper of March and Smith for information technology design work in general and the 1993 paper of Kasanen, Lukka, and Siitonen for the accounting view of this method. Both of these sources contain excellent examples and copious references to related stores of advice. For a more specific example of how design science has changed the world in a way that few scholars can ever aspire to, consider the seminal work of E. F. Codd on relational databases (1970). His work there, barely 10 pages long, was both elegantly simple and theoretically close-to-perfect. Codd's work stands out as an exemplar for AIS researchers interested in design science research projects.

Field Studies

Field based research attracts those who desire first hand observation of corporate business world phenomena and a deeper understanding of "accounting in action" (Ahrens and Dent 1998). Field studies can take several forms. They can (1) examine one company in depth providing a rich description of actual events through first-hand observation (case study), (2) involve data gathered from multiple companies through interviews and questionnaires (cross-sectional), or (3) look at information from one or several companies as they change over time (time-series). In all cases, this technique helps the researcher to remain focused on issues important to practitioners, thereby enhancing the value of academic research. Additionally, field based research can prompt ideas for theory building (Ahrens and Dent 1998; Eisenhardt 1989) or it can confirm existing theories while exposing new relationships (Ahrens and Dent 1998).

There are several risks associated with field based research. Perhaps the greatest difficulty with this methodology is identifying and gaining access to a sufficient number of appropriate organizations. The firms in the study will likely make a significant time commitment to the project, and their direct payoffs may be difficult to identify. Once the project begins, keeping senior management support, controlling for high measurement error and noise, and managing employees who "act strategically" in providing answers or who unintentionally misinform can prove challenging. Therefore, field based research projects need to be carefully designed to provide the greatest opportunities for success. Interviews must be structured, and the data captured must be coded in such a way as to provide research evidence that can be replicated. Also, identifying and controlling for likely difficulties such as personnel or strategic changes during the study can improve the quality of results. Excellent sources of guidance for this type of research include Ahrens and Dent (1998), Baxter and Chua (1998), Stake (1995), Gosse (1993), Trewin (1988) and Yin (1984).

Surveys

Whether face-to-face, telephone, mail, or Web-based, surveys allow researchers to pose pre-defined questions to a sample population[2]. They follow a structured approach to information gathering and can be used to explore new areas or to refine established theories. They have been used successfully to gather limited information about constructs such as AIS implementation characteristics and user satisfaction with systems. Larger scale exploratory work, however, is challenging because codifying a large number of responses to open-ended questions is difficult. Therefore, AIS researchers are more likely to use surveys to gather personal insights about individuals and their organizations. As such, surveys in AIS research are likely to test theories and provide two types of evidence. First, survey development and evaluation can shed light on construct definition. Second, survey responses can be analyzed to test theories.

While survey research is a less costly method of gathering organizational data than field studies, there are two major risks associated with it. First, if the survey is poorly designed, the study will suffer from poor internal validity. In this case, no inferences can be drawn from the study. Second, regardless of the quality of the questionnaire, a low response rate to the survey can doom the project. Many things can influence response rate such as asking inappropriate questions, wording questions poorly, or overwhelming respondents with too many questions. Therefore, the researcher considering survey methodology must be careful to identify research questions that people are likely to participate in, predefine the theory to be tested, pilot test the questions to measure each construct's internal validity, and design the survey to maximize the response rate. Rossi, Wright, and Anderson (1983) have compiled detailed guidelines for each step in the survey process from questionnaire development through data analysis. Their advice ranges from practical ways to minimize postage costs to statistical methods of controlling for non-response bias. The information systems literature also provides guidance. For example, Moore and Benbasat (1991) describe steps for writing questions to measure a new construct, and Sethi and King (1994) describe procedures to refine constructs based upon survey responses.

Laboratory Experiments

Laboratory research in accounting tends to be either experimental or quasi-experimental, and it has several advantages relative to other methodologies. Well-defined experiments begin with deep understanding of the theoretical issues. Based on this understanding, researchers abstract from reality (i.e. create a "pseudo-reality") and manipulate those constructs that are relevant to the research question and theory. They are also able to control for constructs irrelevant to the research question, for example through randomization of participants to experimental treatment conditions. These benefits allow experimental researchers to reveal strong causal inferences, to disentangle effects of factors that often are confounded in archival data, and to study research questions for which archival data is not available (Nelson 1998).

Of course, disadvantages of experimental research also abound (Nelson 1998). Obtaining sample sizes large enough to yield sufficient statistical power is expensive. Operational measures chosen by the researcher may limit the types of inferences that can be made. Designing an experiment or quasi-experiment that rules out alternative explanations in a cost-effective manner is difficult and expensive, especially if one is performing exploratory research. Therefore, experimental results can provide incremental evidence of AIS theories; however, without a well-formulated design grounded in established theory with adequate environmental controls, results can be meaningless. For more detail on experimental and quasi-experimental design principles, readers may refer to Campbell and Stanley (1973), Cook and Campbell (1979), and Kerlinger (1986).

Integration of Research Methodologies

Results of field studies, surveys, and laboratory experiments provide evidence about the usefulness of the constructs, models, methods, and instantiations developed by design science research (March and Smith 1995). These results can then be used to modify or to develop new constructs, models, methods, and instantiations. As discussed in this section, the various methodologies each have strengths and weaknesses the researcher must consider when deciding how to study a particular research question. The relative strengths and weaknesses, and the validity trade-offs between the various methodologies make it crucial for researchers to study the same research question using different approaches. For example, well designed laboratory experiments are likely to have high internal validity as they control for many aspects of their environment, but external validity may be sacrificed in the process. Field studies, on the other hand, have high external validity but are often unable to control complexities in an organization's environment, threatening these studies' internal validity. Thus, convergent results from multiple methodologies produce confidence in those results.

The primitive mappings (edges) of the Research Pyramid yield research questions in AIS that can be studied using these various research methodologies. Some of the primitive mappings result in questions that seem to favor one methodology over another, but all of them can be studied using multiple approaches. The next section of this paper discusses each Research Pyramid primitive mapping, and it suggests how one or more of the four methodologies discussed may be employed to study questions resulting from that mapping[3].

V. Applying the Research Pyramid to AIS Research: Methodological Guidance

This section introduces the use of the Research Pyramid to classify and identify research questions. Each primitive mapping is then examined from the perspective of each of the four methodologies to classify existing AIS research and to propose new AIS research questions.

Guidelines

To use the Research Pyramid, one must consider the relationships among the constructs and there are several overall guidelines to consider while this analysis is performed. Perhaps most importantly, when using the Research Pyramid, one must respect that the constructs are dynamic over time and that they can influence each other in complex manners. Consider that an organization's object system (reality) changes constantly both because of factors in its environment and because of interactions with the other constructs. The organization is likely to affect the mindsets of the people in its reality, and they, in turn, modify the organization through the choices they make in representing the organization on paper and via its information system. Therefore, researchers need to consider each primitive mapping as bi-directional. For example, when looking at the Object-AIS primitive mapping, one could look at the extent to which an object set is represented by two different AIS (from Object to AIS), or one could look at the differential effects of using the two AIS on the object set (from AIS to Object).

Three additional guidelines can help researchers in using the Research Pyramid. First, a firm's performance is one important characteristic of its reality. Thus, if a study measures some aspect of performance (e.g. how well a person performs a task or how much a company's net income increases), then the study is measuring the effect of some construct on the Object set. Second, if a study measures some aspect of user satisfaction, then the study is measuring the effect of some construct on Concepts. Third, the Object construct can be examined in studies that include an actual organization's reality or a "pseudo-reality" that is created by the researcher to represent specific reality characteristics.

Table 2a presents the six primitive mappings and Table 2b presents the five combinations of primitive mappings that can be derived from the Research Pyramid. For each primitive mapping and combination, mapping descriptions or example research questions are provided, existing research papers are identified, and appropriate methodologies for studying research questions in each category are suggested. Many of the ideas in Tables 2a and 2b are expounded upon throughout this entire section.

(insert Tables 2a and 2b approximately here)

Primitive Mappings

While each construct of the Research Pyramid can be described individually, it seems impossible to study just one corner in isolation. Instead, each primitive mapping (edge) between corners seems to serve as the minimum combination necessary to generate interesting AIS research questions. The following sections define each primitive mapping, present research that exists along the mapping, and provide some overall methodological suggestions for future research.

Object-Symbol: Research that develops symbol sets from the real world, that identifies effects of symbol sets on reality, or that evaluates the fit between symbol sets and objects.

Much of the AIS research involving the Object-Symbol primitive mapping is focused in the REA literature. Foundation research in this area described theoretical models (McCarthy 1982; Geerts and McCarthy 1994; 1997a), outlining how the objects should be represented in symbol form. Similarly, research that evaluates the robustness of the symbol set or extends it would be examples of object-symbol work. Examples include Armitage (1985) and Denna, Jasperson, Fong and Middleman (1994) which apply the REA pattern to manufacturing applications, and Denna, Cherrington, Andros, and Hollander (1993) who supplemented the REA pattern with Location to develop an expanded symbol set they refer to as REAL.

Research of the relationship between reality and the symbols used to represent reality is most conducive to a design science approach. Normative work along the Object-Symbol connection usually results from a researcher who perceived some inadequacy in the way accounting systems were being operated and who then proposed a new construct to remedy that inadequacy. Certainly, the "basic historical record" proposals of Goetz (1939), the "events accounting" proposals of Sorter (1969) and the "database accounting" proposals of both Colantoni, Manes, and Winston (1971) and Everest and Weber (1977) all qualify in this regard. A review and a proposed restructuring of these database-oriented ideas is given by Dunn and McCarthy (1997) who also invoke the evaluation framework of March and Smith (1995) for any proposed new work. The most important areas for new design work in this area will likely proceed from an analysis of the patterns of economic activity in the real world to an elucidation of those patterns in literary form (i.e., in the form of a paper or book in the open literature).

Once the patterns described above have been documented, the reverse mapping from symbol to reality can be applied to similar, yet unexplored, object domains in an effort to discern theoretically appealing ideas not yet being either discovered or applied in practice. This void in practical application or discovery might be due to technological infeasibility, or it may be due to prior exploration insufficiently guided by models. The key to such a research project is identifying an unstudied real world object of managerial importance that could only now be reflected with the new symbolic technique.

Surveys and field studies could also be appropriate to evaluate the effect of different symbol sets on organizations. By gathering data on current design methodologies and firm performance, researchers could critically evaluate competing symbol sets or identify when it would be appropriate to use each.

Other example questions involving the Object-Symbol primitive mapping include:

- Do emerging business practices such as electronic commerce transactions and advanced planning activities conform to or extend existing symbol sets?
- Do organizations using different symbol sets perform differently? For example, do firms that use different development methodologies also develop different business processes?

Object-AIS: Research that examines how object characteristics are implemented in AIS, that studies how AIS influence organizational realities, or that evaluates the fit between objects and AIS.

Several research streams have focused on this primitive mapping. First, there is a significant body of literature attempting to measure the value of IT. This work started with the unexpected research finding that productivity had actually declined in the 1970's and early 1980's while investment in IT was increasing significantly. More recent papers have attempted to refine measurements along several dimensions: economy-wide impact of IT (Brynjolfsson and Hitt 1995), IT return on investment (Brynjolfsson and Hitt 1996; Brynjolfsson and Yang 1997), and the impact of IT on firm size and allocation of decision making authority (Gurbaxani and Whang 1991).

Another stream of research that addresses this primitive mapping is the body of work that first studies new generations of software, their characteristics, how organizations adopt them, etc. and then evaluates how well they match the organizations' needs. For example, Davenport (1998) provides an excellent overview of ERP systems, how they have been implemented, and what organizations should do to take advantage of the current technologies. Most of the work in this stream has been practitioner-oriented; however, there are excellent opportunities for academic research as well.

Future academic studies of this mapping in the Research Pyramid are excellent candidates for field research because the field researcher is actively engaged with organizational personnel and has first-hand observations of the AIS. For example, research concerning whether an organization's strategic objectives are being met by their AIS is possible through interviews with IT personnel and top management. Similarly, a time series field study could examine the effects that an AIS implementation has on an organization over a period of time.

Surveys can also be used to evaluate the Object-AIS primitive mapping. Hunton and Flowers (1997) developed a metric to evaluate the sophistication of AIS implementations. They used it to survey organizations to determine which characteristics resulted in performance effects at both an organizational and personal level. Similar work could extend this paper and continue to provide evidence about key system characteristics.

Other example research questions involving the Object-AIS primitive mapping include:

- How well does the firm's AIS support its key economic and business events?
- Which AIS characteristics in existing implementations (such as ERP systems) result in advantages or disadvantages relative to other AIS characteristics? Which AIS characteristics result in the greatest benefits and frustrations for firms?
- How do firms choose to implement different features of AIS application packages? What influences these choices, and what are the outcomes of such decisions?
- How can researchers identify gaps between today's organizational needs and currently available AIS? The goal of such a project would be to provide guidance on how to supplement today's technology to further the AIS literature. Thus, the initial project would be an example of the Object-AIS primitive mapping, but the following work would likely focus on the Object-Symbol mapping.

Object-Concept: Research that evaluates how objects in reality influence people's mindsets or that determines whether people with different mindsets perform activities differently.

It is unlikely that AIS research would not involve either the AIS construct or the Symbol construct. However, much of the research AIS relies on comes from studies that could be categorized under the Object-Concept primitive mapping. For example, the human information processing and audit decision-making literatures have both heavily influenced AIS research[4]. These literatures include studies of knowledge structures, memory, knowledge acquisition, judgment and decision-making. Some studies in those research streams manipulate various aspects of the environment (training, experience, compensation schemes, etc.) and measure the resulting effect of those manipulations on the concepts of individuals and groups. Others examine the concepts of individuals and groups (by attempting to identify knowledge structures and memory characteristics) and their effect on objects. For overviews of behavioral research in accounting and AIS that includes many examples of these types of studies, see Bamber (1993) and Arnold and Sutton (1997).

Surveys, field studies, and laboratory experiments can be used to examine these types of research questions. Survey research can provide insight as to users' concepts, while field work and laboratory experiments can yield evidence as to whether different concepts produce different behaviors.

Examples of research questions that could be studied within the Object-Concept primitive mapping include:

- How do different types of training affect performance? For example, an experiment could be performed to measure how students trained in different AIS courses complete identical tasks. What are the advantages and disadvantages of teaching different approaches to AIS such as controls-oriented, database-oriented, or application-software-oriented approaches?
- Do environmental factors affect how people develop mental models? For example, how does the amount and type of work experience people have affect their representation of business problems? Do people in auditing have different mental models of businesses than people in consulting?

Symbol-AIS: Research that creates systems based upon symbol sets, that examines existing AIS to infer new symbol sets, or that evaluates the fit between symbol sets and systems.

One way to exemplify this primitive mapping is with "proof of concept" projects that verify the feasibility of symbol sets by creating systems. For example, Seddon (1996) developed a new symbol set for manipulating economic transaction data into formula accounting entries. He also developed a working system to demonstrate the symbol set's ability to process challenging accounting transactions. Accounting researchers must realize the importance of doing this on at least a periodic basis in order to maintain credibility with working computer scientists who consider it a routine step on a research journey. Another approach that has been used in projects along this primitive mapping is to compare existing systems with symbol sets. For example, Weber (1986) compared commercially available AIS with the theoretical symbols in the REA literature.

Additionally, field studies and surveys can be used for studying the Symbol-AIS mapping. Studies using the Symbol-AIS primitive mapping could examine what representations within a symbol set are not implemented in an AIS, or may in fact be impossible to implement in any system. Differentiation should be made between those limited by current technology and those that may never be possible. They also could examine what phenomena in the AIS are not covered by the symbol set.

Performing studies from the implementation space to the semantic space involves reverse engineering, a practice that is extremely difficult and time consuming. However, such elucidation is one of the biggest needs in AIS today. This could include analysis and literary exposition of the basic constructs involved in several commercially available ERP packages. Such documentation in journals or books would allow comparisons of production software with different representations of enterprise economic phenomena, and it would enable a host of empirical projects at actual companies assessing such conformance.

Finally, analysis of directed implementations of specific symbol sets could occur in field studies of software vendor operations. Ideally, these studies would include vendors using different symbol sets to create AIS. Their symbols, processes, and resulting AIS could be compared to further the understanding of both constructs and the primitive mapping.

Example research questions that fit into this primitive mapping include:

- What symbol sets are currently being used to develop systems? Are the characteristics of these symbol sets similar to those described in AIS research? If so, which symbol sets are being used and to what extent are they related? If not, what characteristics are in the documentation of the commercial packages that are not in the theoretical symbol sets?
- As new theoretical symbol sets are introduced or expanded, can the new concepts be

implemented in systems by the researchers? Are the new concepts being adopted in commercial implementations?

Symbol-Concept: Research that studies how symbol sets change user/designer mindsets, that examines user/designer mindsets to identify underlying symbol sets, or that evaluates the fit between symbol sets and mindsets.

Survey and laboratory experiments are excellent techniques to use to study how people's concepts influence their preference for one symbol set over another and for determining whether a symbol set is useful in developing people's concepts. Studies focusing on the relationships between users' mindsets and symbol sets will provide evidence of the influence that symbol sets have on students, software vendors, and system users.

Some laboratory experiments have already addressed this mapping. For example, Weber (1996) studied the memory structures of database designers to see if they distinguish between attributes and entities. Design science research in this area includes work addressing the semantic expressiveness of design symbol sets, a.k.a. grammars (Wand and Weber 1993, 1995; Weber and Zhang 1996; Siau, Wand and Benbasat 1997).

Other research questions that could be addressed include:

- Does experience/training with a symbol set change the memory structures of designers?
- Do designers' cognitive characteristics influence their understanding of a symbol set? Their use of the symbol set? Their satisfaction with the symbol set?
- Do system designers prefer one type of documentation (e.g. entity-relationship diagrams) to another (e.g. NIAM)? If so, what psychological factors influence the preference for one over the other?

AIS-Concept: Research that examines how an AIS can influence people's mindsets, that assesses whether people's mindsets affect AIS design/use, or that examines the fit between users' or designers' mindsets and an AIS.

The user satisfaction literature[5] is an example of one stream of research along this primitive mapping. DeLone and McLean (1992), Seddon (1998), and many researchers in between have performed surveys to study the relationship among user satisfaction and other related factors. In those studies, survey results were used to differentiate between the use of systems, system quality, and satisfaction with systems.

Surveys and laboratory experiments are both excellent methodologies for studying this primitive mapping. Surveys can be used to gather information about applications being adopted and those who are using them. Laboratory experiments, as previously discussed, would be able to control the environment to test more developed theories, perhaps providing insights into the user reactions to specific system characteristics.

Other AIS questions on this edge that could be addressed using either surveys or laboratory experiments are:

- Do users prefer one type of AIS to another? Do the preferences vary for users with different cognitive styles?
- Do user mindsets influence AIS feature adoption? For example, do users with certain mindsets adopt more advanced system features, or adopt them more quickly?
- Are AIS designers (users) more satisfied with their AIS when it is consistent with their own mindset as to how well it represents the underlying reality than when it is not consistent?

Combinations of Primitive Mappings

As research in an area progresses, additional research questions can be identified by combining primitive mappings. These research projects are likely to be richer than those focused on an individual edge of the Research Pyramid. However, because of the complexity involved in these projects, they should not be undertaken until thorough analysis of the constructs and primitives has been performed to develop theoretical foundations and measures for the concepts involved in the studies.

The following sections describe the five combinations of primitive mappings. To further illustrate each combination, existing research streams and potential future research questions are presented.

Object-Symbol-AIS

The direct mapping from the real world to the information system is a connection that can be explored with design science; however, some very interesting new AIS research ideas will come from that Object-AIS connection as it is routed through the semantic space of symbols. Such a routing for example would allow a researcher to compare two different symbol-set approaches to building an AIS.

Surveys and field studies of commercial software implementation projects could result in theory development concerning the underlying symbol sets necessary for successful AIS implementations. For example, Hunton and Flowers (1997) used the results of the surveys described in the Object-AIS section to develop a definition for more advanced AIS characteristics which could loosely be described as a set of symbols. A similar stream of research could study ABC systems. ABC principles can be considered as symbols, and studies that examine how closely operating-AIS resemble ABC and the degree to which there are measurable benefits accruing to firm implementation of such ABC systems would be an example of this primitive mapping combination. David (1995) developed a measurement tool to evaluate how closely systems reflected the REA symbol set (an example of the AIS-Symbol primitive). That metric was used in a field study to test whether those systems that were more similar to REA provided efficiency and financial benefits. Cherrington, Denna, and Andros (1996) analyzed how an REA based system was implemented, succeeded, and then failed to be widely adopted by an organization.

Other research questions fitting this combination of primitives include[6]:

- What *firm characteristics* determine the appropriate *symbol set* and *AIS choices* for *beneficial IS implementations*?
- Are different industry-specific *software packages* based upon similar *symbol sets*, or are there different *sets*? If so, what *activities in the industry* demand different *symbols*? In a given *industry*, how closely do the *packages* match these *symbols*?

Object-Symbol-Concept

Whereas the Object-Symbol primitive cannot easily be studied using surveys or laboratory experiments, inclusion of the Concept construct creates the opportunity for many research questions that can be addressed with these methodologies. Several AIS studies fit within this combined primitive mapping. Amer (1993) examined the relative performance of users of entity-relationship versus relational models for an audit review task. Dunn and Grabski (1997) examined the effect of different accounting models and different cognitive characteristics on users' performance, and Dunn and Grabski (1998a) examined the effect of students' field dependence on conceptual modeling performance. Gerard (1998) examined the quality of designs generated by designers with memory structures consistent with the REA model versus those of designers with non-REA memory structures. Additional examples of potential research questions examining the Object-Symbol-Concept mapping include:

- Is a designer's *concept* of one *symbol set* more consistent with his *concept* of the underlying reality than are his *concepts* of other *symbol sets*? If so, does *firm performance* improve when the *designs* are the result of the consistent *symbol set*?
- Do system designers with different *psychological characteristics* or who are in different *environments* have different *perceptions* as to how well one *symbol set*, as compared to some other *symbol set*, represents an *organization's underlying reality*?
- Do users who have been exposed to different *symbol sets* have different *perceptions of their organizations*? Do they *perform* their tasks differently than they did before? Does their *performance* differ from that of other users?
- If training or experience with a particular *symbol set* changes designers' *memory structures*, does the change in *memory structure* lead to some *benefit* such as *more efficient or more effective designs*?

Symbol-AIS-Concept

As in the previous section, expanding the Symbol-AIS primitive mapping to also include Concept enables the use of laboratory experiments or surveys. While people's mindsets are not easily captured, these techniques allow us to measure certain aspects of their mental approaches and behaviors that reflect those mindsets. As noted in the AIS-Concept section, user satisfaction studies for which there are comparative AIS based on different symbol sets would be categorized as Symbol-AIS-Concept.

Other research questions that could be addressed here in the Symbol-AIS-Concept realm include:

- Do software designers with a *mindset* that reflects a certain *symbol set* create *systems* more closely related to that *symbol set*?
- Do users of *systems* with a *mindset* consistent with one particular *symbol set prefer* the *system* more than users of *systems* determined to be inconsistent with that *symbol set*? Does this *preference* vary according to user's *psychological characteristics*?
- Do *preference differences* as noted above depend on the consistency between the *symbol set* and/or the *implemented system* and the user's *view of the underlying reality*?

Object-AIS-Concept

This three-construct mapping identifies projects that examine how user perceptions interact with their AIS and reality. These studies can focus on performance benefits accruing to different types of systems when users have specific backgrounds, or they can examine user perceptions when placed in different organizations with differing systems. Examples of AIS research that has examined the Object-AIS-Concept mappings include many studies in the expert systems body of literature. For example, Steinbart and Accola (1994), Pei, Steinbart and Reneau (1994), Odom and Dorr (1995), and Hornik and Ruf (1997) examined the effects of different characteristics of expert systems on the attitudes and performance of users.

Group support systems (GSS) is another category of research that fits well along this primitive mapping. A typical study in this category examines the effect of one or more group support systems on user performance, communication patterns, and attitudes. Bamber, Hill, and

Watson (1998) provide a framework for studying group support systems in an audit context and propositions for future research, much of which is systems-related auditing research.

A third stream of research along this primitive mapping is Human-Computer-Interaction (HCI). Card, Moran, and Newell (1988) and Baecker, Grudin, Buxton, and Greenberg (1998) provide excellent reviews of this literature. One example of HCI in AIS research that studies this mapping is Hunton (1996). He presents results of a laboratory experiment that examined the effect of different combinations of users' expected and actual participation in a system development project on user performance (Object-AIS) and attitudes (AIS-Concept).

Laboratory experiments have been the most commonly used method in all three of the above mentioned research streams; however, this mapping could also be studied using field studies and surveys. Some example research questions examining this combination mapping are:

- Do different *perceptions* as to how well an *AIS* represents the *underlying reality* correspond with different *performance levels*?
- Do AIS users *perform better* with *AIS* that are consistent with their *mindsets* than with *AIS* that are not consistent with their *mindsets*?
- Do organizations *perform better* when system designers develop *AIS* that are consistent with their *mindsets* than when designers develop *AIS* that are not consistent with their *mindsets*?

Object-Symbol-AIS-Concept

Some studies examine combinations of primitive mappings that encompass all four constructs of the Research Pyramid. Any of the studies in the Symbol-AIS-Concept category could be extended to cover Object by examining the results of different symbol sets and the resulting AIS on the performance of users or designers as well as on their concepts. Chan, Wei, and Siau (1993) studied user performance and attitudes resulting from the use of two different systems that were based on two different symbol sets. Examples in the AIS literature that have examined combinations of all four constructs include (1) Gibson (1994) who examined user performance across different symbolic screen layouts or feedback types and (2) Dunn (1995) who first created two AIS interfaces from two symbol sets, and then included users' concepts (as proxied by training in accounting and in data modeling) as independent variables along with the AIS interface, and finally evaluated user performance on an information retrieval task.

Examples of extended questions from the Symbol-AIS-Concept section that could be expanded to also include Object are as follows:

- Do users of *AIS* determined to be consistent with one particular *symbol set prefer* the *AIS* more than users of *systems* determined to be inconsistent with that *symbol set*? Does *performance* differ for these users?
- Does *preference* for *AIS* that are consistent with one *symbol set* versus another vary according to users' *psychological characteristics*? Does *performance* with these *AIS* also differ according to users' *psychological characteristics*?
- Do *preference* and *performance* differences as noted above depend on the consistency between the *symbol set* and/or the *implemented system* and the *user's view of the underlying reality*?

VI. Using the Research Pyramid to Identify Opportunities

The Research Pyramid's greatest benefit is likely to be its ability to help researchers identify opportunities that extend their research area along new primitive mappings.

Specifically, it can be used to identify primitive mappings within a research stream that have not yet been studied exhaustively, and it can assist in generating potential research questions along each primitive mapping. As an illustration, the Research Pyramid is applied to one major area of AIS research: the Resources-Events-Agents (REA) AIS model developed by McCarthy (1982) and extended by Geerts and McCarthy (1994;1997a).

Step 1

The first step in applying the Research Pyramid to REA is to determine how the current literature maps to the constructs (points) in the Research Pyramid. In this case, the REA pattern is an enterprise information architecture (Symbol set) that can be used to design integrated enterprise information systems (AIS) that capture a broad range of data about enterprise reality (Object set). Additionally, teaching and using the REA pattern has influenced the mindsets (concepts) of students and professionals in a manner that constantly asks them to weave together the economic components within and between business processes.

Step 2

Next, the researcher should attempt to categorize the existing literature along the Research Pyramid mappings. Looking at Tables 2a and 2b, one can see that since 1982 when REA was introduced, the majority of work in this research stream has focused on the Object-Symbol and Symbol-AIS primitive mappings using design science techniques to further define and evaluate the robustness of the REA model. Not until recently have studies begun to explore the Symbol-Concept-Object and the Object-Symbol-AIS primitive mappings with laboratory experiments and field studies.

Step 3

Once the categorization is complete, the researcher should evaluate the current literature, and identify opportunities to extend it. While there appear to be holes in the REA research along several mappings, such as Object-AIS and AIS-Concept, all potential REA projects require the REA Symbol set. Therefore, the mappings that do not include Symbol are ignored. Having done that, one challenge in performing research along several mappings is to measure whether the AIS or Concepts are aligned with the REA pattern. Thus, REA research along two primitive mappings, Symbol-Concept and Symbol-AIS, is critical to extending this literature. For example, to further REA research in the Symbol-AIS primitive mapping and to advance it into the AIS-Concept and Symbol-Concept primitive mappings, researchers must be able to determine whether AIS or Concepts (or both) are more or less like REA. To date, researchers such as David (1995), Dunn and Grabski (1998b) and Gerard (1998) have had to develop metrics to measure the degree to which the AIS or Concepts matched the REA pattern. David (1995) created a questionnaire for actual accounting system implementations. This metric was utilized further by Jobe (1997). Dunn and Grabski (1998b) developed a questionnaire to determine whether users' mindsets about AIS were more similar to REA or to the traditional debit-credit-account model. Gerard (1998) used REA training as a proxy for user mindsets and developed memory structure test instruments to confirm that proxy.

In addition to identifying a need for studies that focus on theoretically developed measurement tools, evaluations of primitive mappings in existing REA research may also spark new research ideas. For example, while most of the existing Symbol-AIS literature has been "proof of concept" work to show the viability of REA systems, there are certainly opportunities for REA research along this mapping that focus on actual AIS implementations and how they match the REA pattern. Examples include:

- Implementation of REA systems on more advanced platforms such as object-oriented systems or ontology definition languages, provided such research furthers the understanding of the REA symbol set, rather than applying a new technology to existing REA concepts.
- Analysis and literary exposition of the basic constructs involved in ERP packages, as was recommended in the Symbol-AIS section, comparing the constructs in the ERP packages with REA principles of representation.

While there are examples of REA research for both the Object-Symbol-AIS and Symbol-AIS-Concept mapping, there are many additional opportunities in these areas. For example, there are several Symbol-AIS-Concept questions that could be addressed such as:

- Do users with REA mindsets prefer to use systems with specific characteristics? Which characteristics?

- Do users prefer REA systems over non-REA systems?

Finally, while the majority of REA-related research has focused upon the Object-Symbol and Symbol-AIS primitive mappings, there are still opportunities to use design science techniques along these mappings to further the understanding of the REA pattern. However, seeing the density of projects along these dimensions should alert researchers to the importance of serious consideration of theoretical foundations and the need to truly extend the pattern, rather than rely on technology advances for minor restatements. The following are examples of possible research opportunities in REA in the Object-Symbol area that would truly extend the literature:

- Extensions to the basic set of primitives in the manner shown by Geerts and McCarthy (1994, 1997a) who incorporated an explicit representation of the enterprise value chain into REA to weave the individual process templates together in an integrated way. Other extensions could include adding other components to the basic pattern or expanding the exposition of the pattern components to include more detailed methodological guidance[7].
- Additional work in integrating REA with other similar process models of the firm (from the supply chain literature or from the strategic ABC literature, for example). This would probably involve converting REA ideas into the exposition mechanisms of these related fields or vice-versa. Seemingly, these other fields' expositions consist primarily of narratives, so putting them into the more consistent notation of data modeling or other representation formalisms might make the comparisons and integrations work better.

Step 4

After identifying a research question of interest and evaluating it based on the Research Pyramid primitive mappings, the researcher must decide what methodological approach to take. Table 2a, Table 2b and Section V provide some guidance as to the choices of appropriate methodologies for the various primitive mappings. If the primitive mapping is such that the researcher has a choice between a lab experiment and a field study, the following should be considered. Laboratory experiments may provide opportunities to control for environmental factors and to measure user concepts better. However, the tradeoff is that the objects studied are a pseudo-reality. If the researcher is concerned that the results of a laboratory study will not generalize to the actual physical reality, the researcher may choose instead to use a survey and/or a field study.

VII. Conclusion

This paper describes the Research Pyramid as a framework to categorize existing literature, and, more importantly, to help identify new research frontiers. When using the Research Pyramid to analyze existing literature, research streams often have one or two primitive mappings that have been most naturally studied. While this paper is not meant to provide an exhaustive classification all the AIS literature, Section V illustrates this phenomenon as it provides insights into several research streams as illustrations of the primitive mappings and combinations. For example, human-computer-interaction and user satisfaction seem naturally to include the Concept-AIS mapping. IT valuation and organizational theory studies fall within the Object-AIS mapping, whereas human information processing studies (including both individual and group-level judgment and decision-making) seem most likely to involve the Object-Concept mapping. Thus, using the Research Pyramid to classify the existing literature within a broad research stream identifies the dominant primitive mappings.

Once the prior work has been classified according to the Research Pyramid, the primitive mappings that have not been thoroughly studied help to identify gaps in the literature. That is not to say that every primitive mapping must be studied for every research area, but that a researcher seeking a new project should consider whether a useful combination can be made by extending into another primitive mapping. It seems particularly useful to consider the mappings that include one of the constructs in the dominant primitive mapping.

At this point, the Research Pyramid is better suited to generating new projects than it is to exhaustively classifying existing AIS projects. However, this is not a weakness as most retrospective categorizations fray at the edges when an attempt is made to impose structure where none was actually intended by the original authors. Moreover, its applicability to new areas is more important, as new projects are the lifeblood of the field.

To illustrate, the Research Pyramid can help AIS researchers focus on identifying and explicitly defining AIS characteristics and current symbol sets. With these definitions researchers will be able to study the impact of specific characteristics on organizations, on their AIS, and on their users' conceptual understanding of the organization and its systems. If researchers within a research stream study each primitive and combination mapping of the Research Pyramid, a thorough, theory-driven view of corporate AIS will be developed. As described earlier, this research can be performed using design science, field-based techniques, surveys, and laboratory experiments. If all methods are applied, the understanding of basic AIS constructs, their theoretical relationships, and their current effects on organizations will be enriched. This will provide evidence of what system characteristics are valuable to different types of organizations. Similarly, a better understanding of how the mindsets of users and developers influence project success will be developed, as will more insights into how different systems influence users. The outcome of these endeavors has the potential to provide focus to future AIS research efforts and to influence students, system developers, and business organizations.

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[1] This definition has been influenced by current textbooks, especially Hollander, Denna and Cherrington (1996).

[2] Questionnaires are often used to direct field studies, so "surveys" can be used as part of field studies, or as the sole data gathering approach. In this paper, "surveys" are metrics used for larger sample studies. Therefore, there is overlap between survey methods and field studies, but we will discuss these techniques as though there is a well-defined separation between them. In general, survey research can be used to further refine the results of field studies.

[3] The AIS research questions provided here are intended only as examples to stimulate researchers' thinking about other interesting AIS research questions. Obviously an exhaustive list of possible research questions is infeasible.

[4] This is not to say that all human information processing and audit decision-making research studies outside of AIS fit only into this primitive mapping. Some of these also may incorporate symbol sets. And certainly some of the papers we later classify as Object-AIS-Concept and Object-Symbol-AIS-Concept could be considered part of the human information processing and audit decision-making literatures.

[5] This generalization of user satisfaction literature onto this primitive mapping is not intended to restrict all user satisfaction studies to only this mapping. Any studies within this area that look at performance measures also include the Object construct, and it is possible for user satisfaction studies to include symbol sets. However, the AIS-Concept mapping seems to be the dominant primitive mapping for this literature.

[6] Because identifying the Research Pyramid constructs in the combination primitive mappings may be less clear than in the two-way mappings, these constructs are identified in italics in the research questions posed in this section.

[7] Good examples of work that proposes to expand REA representation levels are David (1997), and Geerts and McCarthy (1997b).

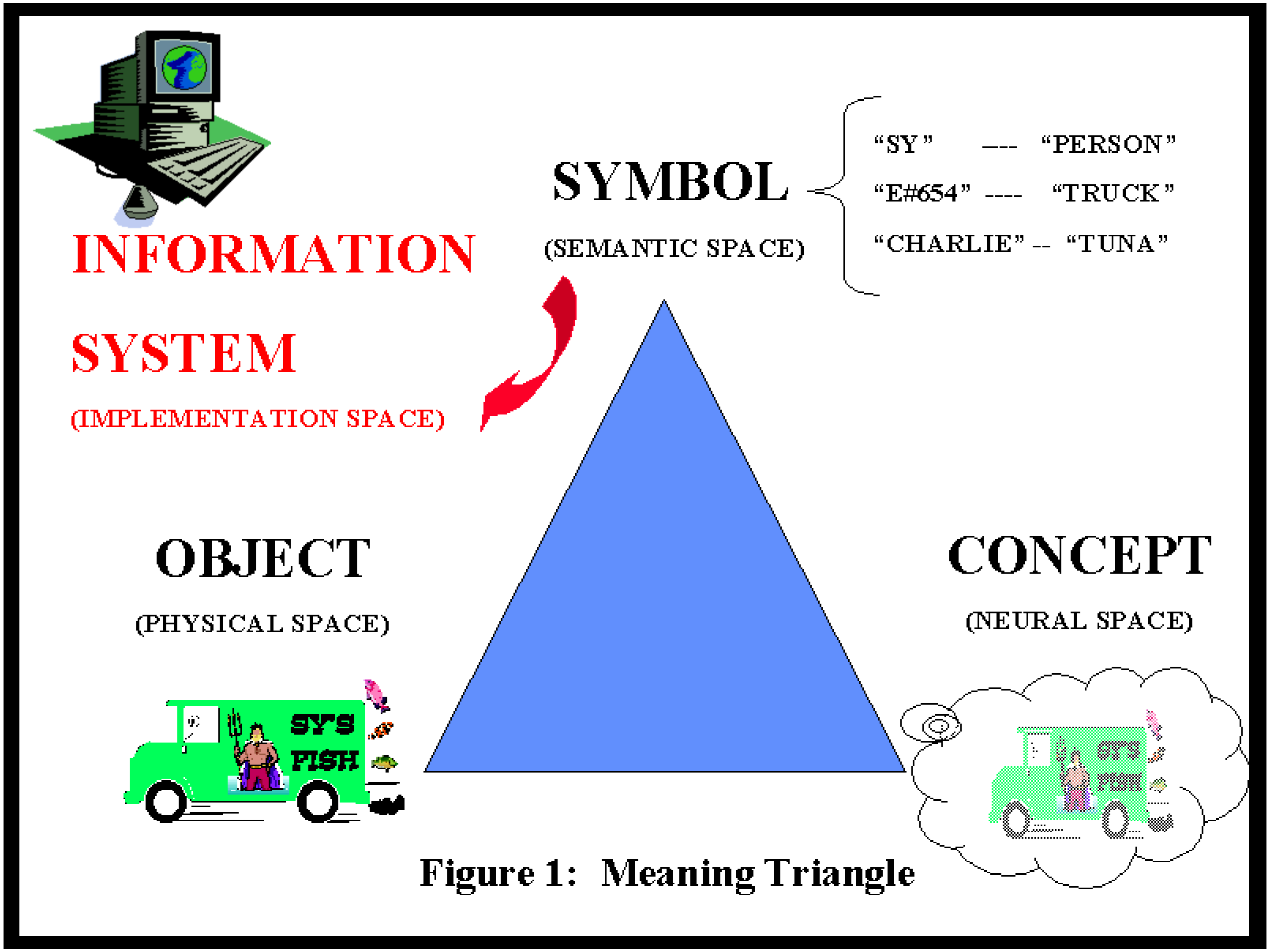

Figure 1: Meaning Triangle

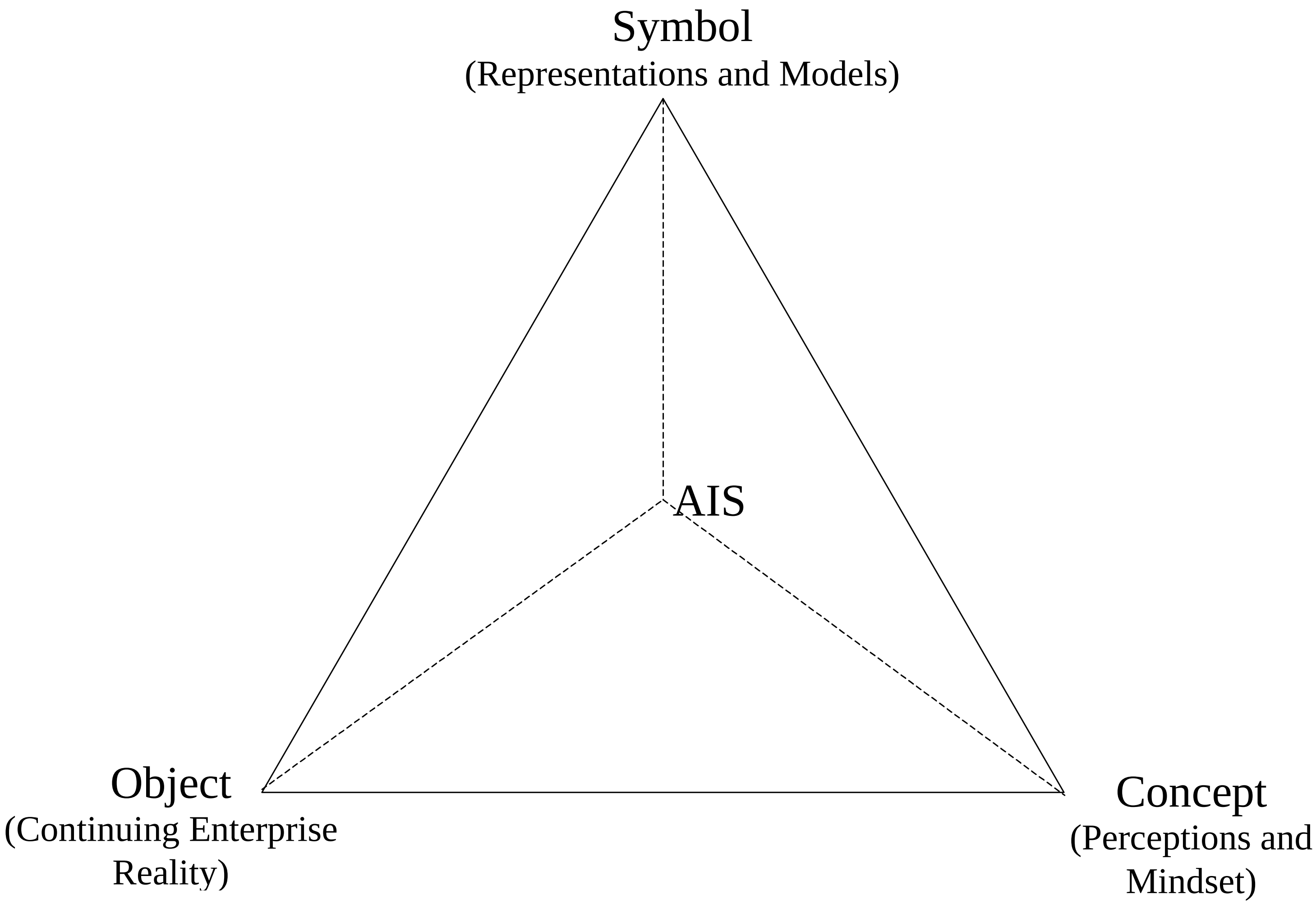

Figure 2: Research Pyramid

Table 1: Terms Used to Describe Model Components*

Objects in Physical Reality	Concepts	Symbols	Components of Information System
Physical space	Neural space map	Semantic space map	Implementation (cyber) space
Pattern in the world	Pattern in our mind	Pattern in the literary form	Patterns in databases and programs
Enterprise Reality	Enterprise Mindset	Enterprise Information Architecture	Enterprise Information System

*Terms used in this table are adapted from, but are not always found specifically in Sowa (1997), Haeckel and Nolan(1993), Beedle and Appleton (1998), and McCarthy (1979, 1982).

Table 2a: Overview of the Research Pyramid Primitive Mappings

(Research in italics identifies REA-related work)

Pyramid Primitive Mapping(s)	Mapping Descriptions	Existing Research Examples	Appropriate Methodologies
Object-Symbol	• Develop symbol sets from the real world (examples of already existing sets include A=L+OE, REA) • Identify the effects of symbol sets on reality • Compare two symbol sets to evaluate the fit between the symbol and objects	Goetz (1939) Sorter (1969) Colantoni et al. (1971) Everest and Weber (1977) *McCarthy (1979, 1982)* *Armitage (1985)* *Denna et al. (1993)* *Denna et al. (1994)* *Geerts and McCarthy (1997a)*	Design science Field research Survey
Object-AIS	• Examine how object characteristics are implemented in AIS • Examine how AIS influence organizational realities • Evaluate how objects and AIS match	Weber (1982) Meservy et al. (1986) Wand and Weber (1989) Straub (1990) Gray (1991) Gurbaxani and Whang (1991) Brynjolfsson and Hitt (1996) Basu et al. (1997) Davenport (1998)	Design science Field research Survey
Object-Concept	• Study how objects in reality influence people's mindsets • Determine whether people with different mindsets perform activities differently	Many human information processing and audit decision-making studies	Survey research Lab experiment Field study
Symbol-AIS	• Create systems based upon new symbol sets as proofs of concept • Examine AIS to infer new symbol sets	*Gal and McCarthy (1983, 1986)* *Weber (1986)* *McCarthy and Rockwell (1989)* Seddon (1996)	Design science Field study Survey

Pyramid Primitive Mapping(s)	Mapping Descriptions	Existing Research Examples	Appropriate Methodologies
	• Evaluate the fit between symbol sets and systems	Parsons (1996) O'Leary (1998)	
Symbol-Concept	• Study how symbol sets change user/designer mindsets • Examine user/designer mindsets to identify underlying symbol sets • Evaluate the fit between symbol sets and concepts	Wand and Weber (1993;1995) Weber and Zhang (1996) Siau et al. (1997)	Design science Survey research Lab experiment Field study
AIS-Concept	• Examine how an AIS can influence people's mindsets • Determine whether/how people's mindsets affect AIS design • Evaluate the fit between AIS and designers/users mindsets	DeLone and McLean (1992) Seddon (1998)	Survey research Lab experiment Field study

Table 2b: Overview of the Research Pyramid
Combinations of Primitive Mappings

(Research in italics identifies REA-related work)

Combination of Pyramid Primitive Mapping(s)	Example Research Questions	Existing Research Examples	Appropriate Methodologies
Object-Symbol-AIS	• Do AIS created with a particular symbol set better match the underlying reality than other AIS? • Do AIS created with a particular symbol set positively affect objects in the organization's reality?	Vasarhelyi and Halper (1991) *David (1995)* *Cherrington et al. (1996)* Hunton and Flowers (1997) *Walker and Denna (1997)* David et al. (1998)	Design science Field study Lab experiment

Combination of Pyramid Primitive Mapping(s)	**Example Research Questions**	**Existing Research Examples**	**Appropriate Methodologies**
Object-Symbol-Concept	• Is a designer's concept of underlying reality more consistent with one symbol set than another, and does this consistency lead to better designs? • Does use of different symbol sets lead to different attitudes and performance behaviors?	Sutton (1990) Amer (1993) Wand and Wang (1996) *Dunn and Grabski (1997)* *Dunn and Grabski (1998a,b)* *Gerard (1998)*	Survey Lab experiment Field study
Symbol-AIS-Concept	• Do designers with a particular mindset choose to create systems whose underlying symbol set matches the designer's mindset? • Is a user's performance affected by the consistency of his mindset with the symbol set underlying the AIS he is using?	Ahrens and Sankar (1993)	Survey Lab experiment Field study
Object-AIS-Concept	• Do users' (designers') mindsets affect their use (design) of an AIS and thereby affect objects in their organization's reality? • Do objects in an organization's reality affect AIS users or designers mindsets?	Amer (1991) Chu (1991) Bamber et al. (1995) Hunton (1996) Steinbart and Accola (1994) Pei et al. (1994) Odom and Dorr (1995) Hornik and Ruf (1997)	Survey Lab experiment Field study
Object-Symbol-AIS-Concept	• Do users (designers) of AIS based on two different symbol sets have different preferences and different performance? • Do users (designers) of AIS based on two different symbol sets exhibit different performance depending on their mindsets?	Chan et al. (1993) Gibson (1994) *Dunn (1995)*	Survey Lab experiment Field study