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The REA Ontology to Supplement Teaching Data Flow Diagrams

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ABSTRACT

Systems Analysis and Design is a core component of most information systems curricula, and generally includes coverage of process modeling with data flow diagrams. In order to relate process modeling to something with which all students are familiar, the content of a traditional Systems Analysis and Design course can be supplemented with an ontological framework. This manuscript proposes that an ontology from accounting literature (REA) be used to supplement traditional modeling approaches. The REA Ontology incorporates elementary accounting concepts familiar to many business students, and as a consequence makes contextual learning possible. This manuscript points out several synergies between the REA Ontology and data flow diagrams, and notes that the contextual learning factor enhances student learning. As a result, students are able to develop an efficient and enriched mental concept of data flow modeling and the business processes the models seek to capture.

Keywords

Systems Analysis and Design, REA Modeling, Data Flow Diagrams, REA Ontology.

INTRODUCTION

A Systems Analysis and Design (SAD) course is a core component of an information systems (IS) curriculum. This course typically contains a rather broad set of topics, ranging from planning strategies, project management, system analysis, and system design to related topics such as object-oriented development methodologies. The breadth and depth of topics that are frequently covered in SAD make it a difficult course for not only students, but also for instructors.

One of our goals as educators is to build a solid and broad foundation of knowledge for our students. The better that we integrate long-accepted development strategies such as structured analysis and design with other business disciplines, the more solid the foundation becomes. By using the extremely adaptable Resources-Events-Agents (REA) model (McCarthy 1982) to perform this integration, an SAD course can provide IS students with a perspective to extend familiar concepts, such as the duality of the accounting transaction. By explaining new material in terms of concepts already familiar to the IS student, both understanding and retention increase. Use of REA also links IS students' understanding of processes within an organizational context to widely accepted systems development strategies and database design. Similarities exist between the REA model and logical ERDs, and it has been argued (Trimmer, LeRouge, and Pinsker 2002) that students in IS courses might better understand and relate to the use of REA models rather than ERDs. This paper makes the point that the REA Enterprise Ontology can be used to better explain process modeling as well.

Our approach to process modeling supplements the concepts presented in traditional data flow diagrams (DFDs) (Gane and Sarson 1979) with the accounting information system (AIS) perspective of McCarthy's REA Ontology. The combination of two approaches offers students multiple perspectives for understanding the same problem. Because IS students taking the SAD course are typically in the early stages of integrating a wide range of business concepts (Trimmer and Parker 2004), this approach helps them utilize material learned elsewhere in the undergraduate business program with an integrated framework for business processes.

This manuscript provides a discussion of data flow diagrams, the REA model and the REA Ontology. It next examines the parallels between the REA Ontology and the DFD approach for process modeling. Those parallels are demonstrated in both graphical and textual examples. The manuscript concludes with a discussion of the advantages of utilizing the REA Ontology to assist in teaching process modeling, as well as reinforcing concepts typically found in an undergraduate IS curriculum.

AN OVERVIEW OF THE REA MODEL VS. MORE ESTABLISHED MODELS IN AIS AND IS

Process modeling is a technique for organizing and documenting the structure and flow of data through a business system's processes. It involves graphically representing the processes involved in capturing, manipulating, storing and distributing data between a system and its environment and between system components (Hoffer, George, and Valacich 2002). A data flow diagram is a type of process model used to depict the flow of data through a system, and the work or processing performed on the data as it moves through the system.

Data-Flow Diagrams

In the late 1970s data-flow diagrams were introduced for structured systems analysis and design (Gane and Sarson 1979). DFDs present an overview of system inputs, processes, and outputs by graphically depicting the flow of data from external entities into the system, the flow of data from one process or transform to another, and the logical storage of data. A series of layered DFDs reveals an increasing level of detail and can be used to represent and analyze detailed procedures within a system.

Data flow diagrams using the Gane and Sarson notation are made up of four symbols. The square represents an entity (also called an external agent) that is external to the system and that can send data to the system (known as source or origin of data) or receive data from the system (known as sink or destination of data). A rectangle with rounded edges represents a process or transform in which data is transformed from one form to another. Arrows are used to represent data flows, and show the movement of data from one point to another. The head of the arrow points to the data's destination. Finally, an open-ended rectangle is used to indicate a data store, which is used to show a repository of data that allows storage and retrieval of data. DeMarco and Yourdon provide a slightly different symbol set for data flow diagramming (DeMarco 1978).

Development of a data flow diagram begins by creating a context diagram that shows a single process that represents the system, as well as external entities and data flows to or from the system, i.e., the system inputs and outputs (see Figure 1). The next level, referred to as Level 0, provides a detailed depiction of the functional decomposition of the context diagram by depicting system processes (see Figure 2). Each process on Level 0 can be decomposed into a more detailed child diagram, and these are generally referred to collectively as Level 1 (see Figure 3). Each of the processes on these child diagrams can in turn be decomposed into Level 2 diagrams, and so forth, concentrating on how the data is processed in each step. Exploding processes on a DFD into subprocesses provides greater detail about data movement and transformation. The process of decomposition continues until there is a low enough level of logic to explain elementary processes (Hoffer et al. 2002). Figures 1 through 3 use the Gane and Sarson symbol set to present examples of the various levels of a DFD.

The REA Model

McCarthy (1979, 1982) proposed his seminal REA model as a means for an enterprise to capture the essence of economic exchanges between two parties. The REA model provides an alternative framework for modeling an organization’s economic resources, economic events, economic agents, and their interrelationships (see Figure 4). Resources are organization assets that are able to generate revenue. These can be tangible or intangible, but must be under the control of the organization. Resources do not include artifacts that can be generated from other primary data. Events are some phenomena that bring about changes in resources. Events provide a source of detailed data in this modeling approach. There are three classes of events: operating events, or activities that produce goods or provide services; information events, or activities associated with recording, maintaining, and reporting information; and decision/management events, or activities that lead to decisions being taken. The REA model addresses only operating events. Agents participate in events and can affect resources. They have discretionary power to use or dispose of resources. Agents can be an organization or individual either inside or outside the organization that is capable of controlling economic resources and interacting with other economic agents. An extension of the REA model, known as the Resource-Event-Agent-Location (REAL) model adds location as a modeling element (Hollander, Denna, and Cherrington 2000). Location generally refers to the location of a resource or event.

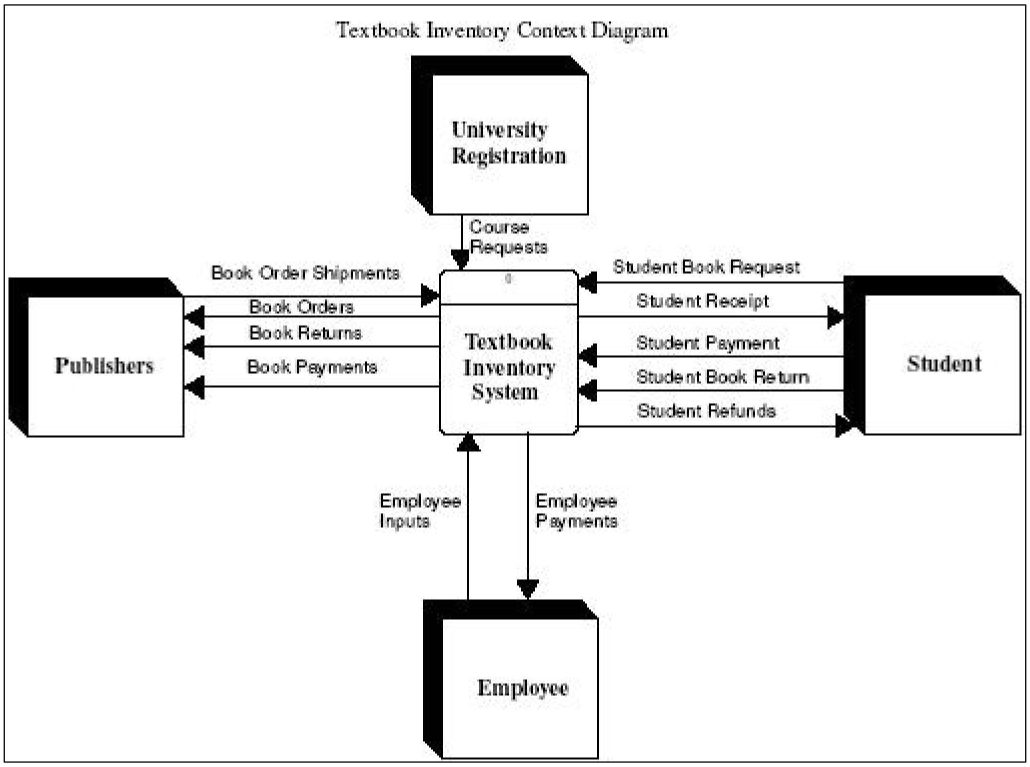

Figure 1. Bookstore Context Diagram

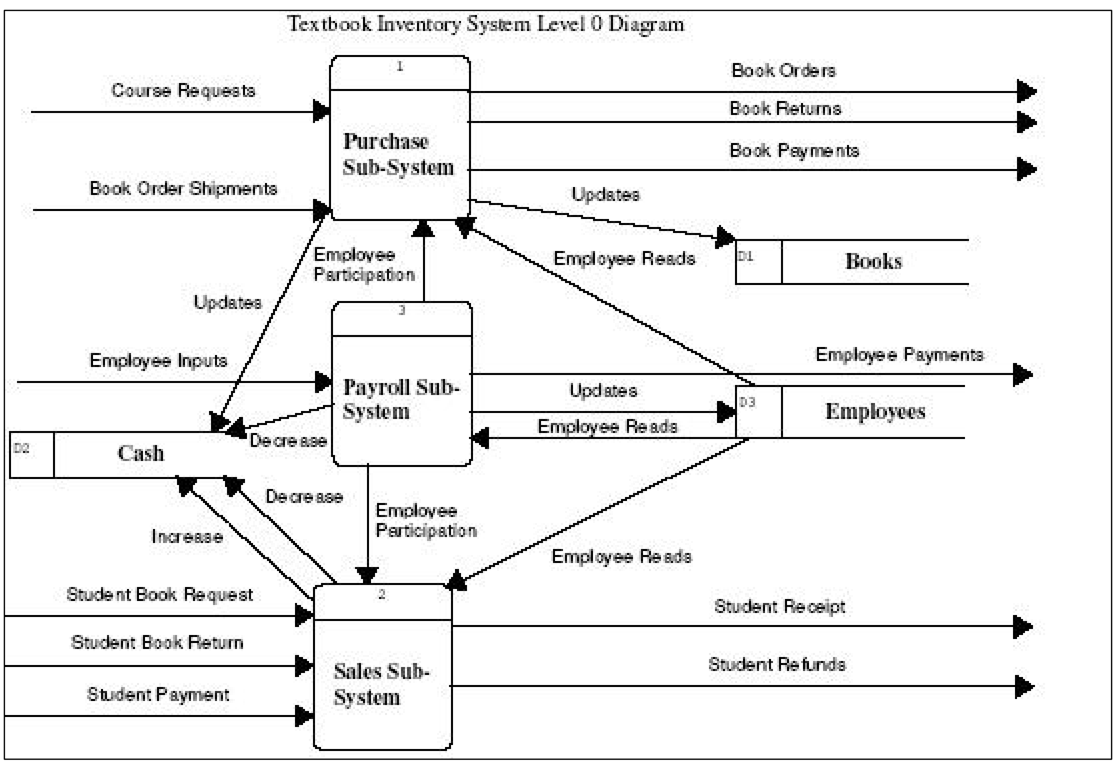

Figure 2. Bookstore Level 0 Diagram

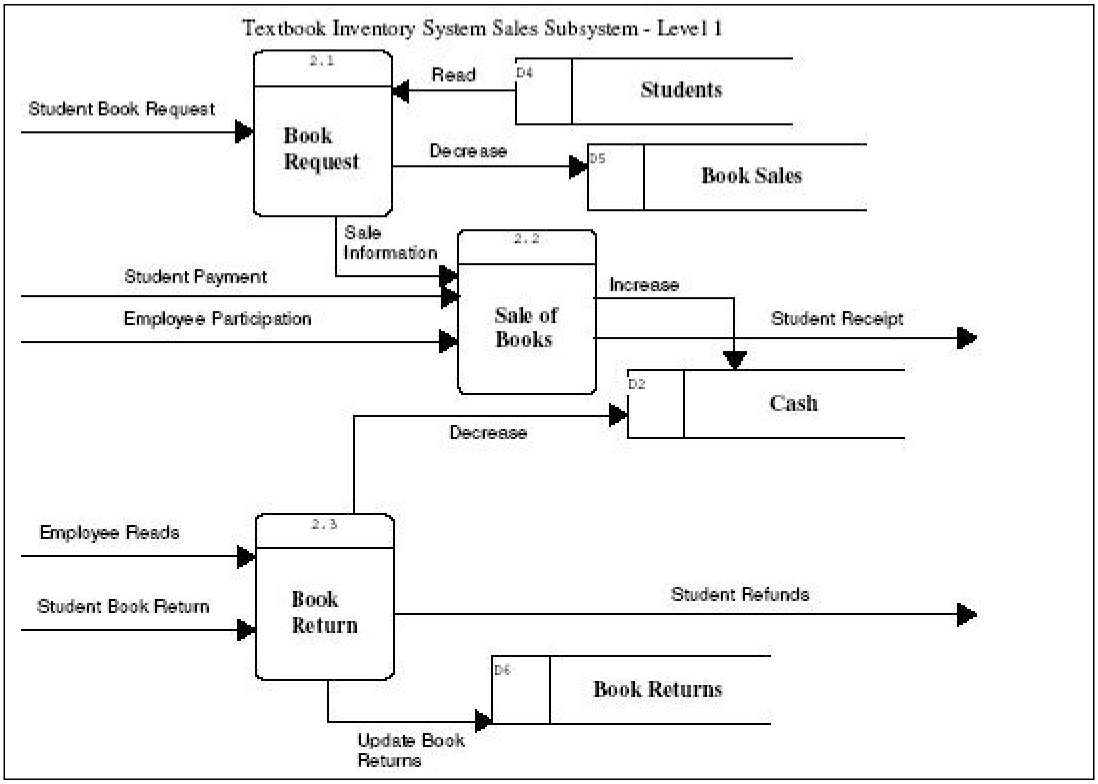

Figure 3. Bookstore Level 1 Diagram for Sales Process

The REA model is deeply grounded in accounting and economic theory (Geerts and McCarthy 1997) and designed to provide information in order to answer five questions about an economic exchange (Denna and McCarthy 1987; Hollander, Denna, and Cherrington 1995): What happened? When did the exchange occur? What roles were played and by whom? What kind and how many resources were used? Where did the exchange occur? The generalizability of McCarthy's model is derived, in part, from the typical debit-credit model in accounting. The model represents the duality of the economic event presented to students in introductory accounting courses.

Focusing on an economic event as a key business occurrence, McCarthy illustrates that the nature of an event is that an agent gives up a resource in receipt for another resource. For example, the script for a typical business transaction is as follows:

> A customer (external agent) enters a retail establishment and shops for one or more items (resource). The customer selects these items and proceeds to pay for them (event) at a checkout stand manned by a checkout clerk (internal agent). The customer exchanges currency for the basket of goods. Likewise, the retailer receives said currency and gives up said basket.

McCarthy's perspective provides a starting point for investigating organizational events at a general level. In the preceding script, a change in scenario from a brick and mortar retail establishment to the World Wide Web does little to alter the essence of the economic event. A full REA-designed information system would emphasize the impact of recording the essential characteristics of business events and, with proper authority, would provide information to both internal and external enterprise stakeholders.

In its simplest form, the REA approach models the relationships in an economic exchange by recording the relationships between parties in terms of stock flows and control. Specifically, stock flows refer to the relationship between events and resources and control refers to the relationship between events and agents. Figure 4 is adopted from McCarthy (1982) and displays the simplified REA model.

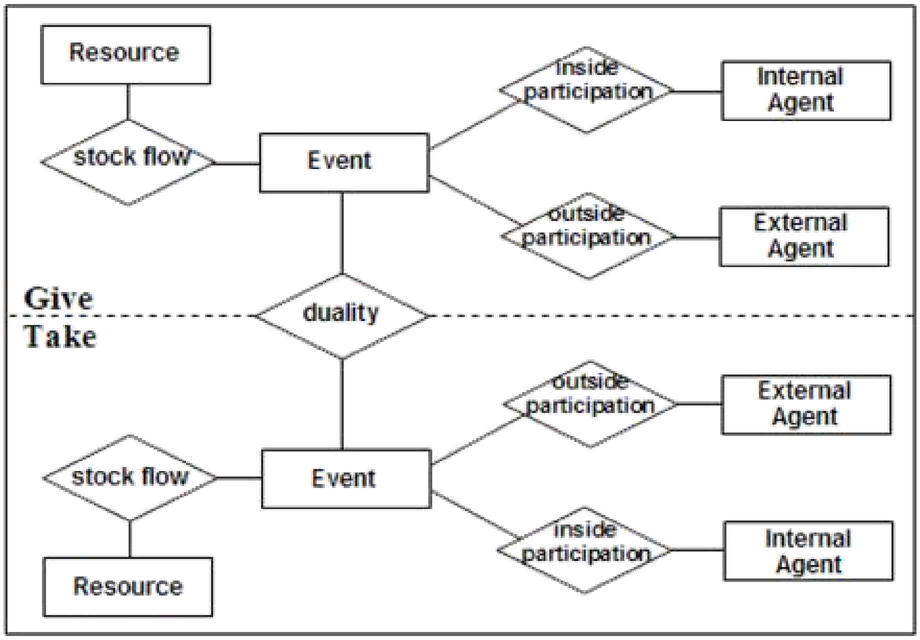

Figure 4. Generic REA Exchange Model (Adapted From McCarthy, 1982)

The REA Ontology

The REA model has proved so useful and intuitive for better understanding of business processes that it has become one of the major accounting modeling frameworks for both traditional enterprises and e-commerce systems. With its conceptual modeling heritage, the original REA model resembles an ontology in many respects (Geerts and McCarthy 2000), but it has recently been extended to include concepts for understanding the processing aspects (processes, recipes) in addition to the economic aspects (ECIMF 2003).

The REA Enterprise Ontology is an extension of the REA model to the enterprise (McCarthy 2003; Dunn et al. 2005). The REA Ontology is a specification of the declarative semantics involved in a business collaboration, or more generally in a business process (UN/CEFACT 2003). "The objective of an enterprise ontology is the conceptualization of the common economic phenomena of a business enterprise unaffected by application-specific demands" (Geerts and McCarthy 2000, 6). The core economic phenomena that are included in the REA Ontology are exchanges, resource-agent dependencies, resource dependencies, agent dependencies and commitments. Many of these were present in the original REA model, but others represent extensions to the original model (Geerts and McCarthy 2000). Dunn, Cherrington, and Hollander (2005) present a value-chain viewpoint that categorizes overall business functions into five broad processes: financing, acquisition/payment, payroll (employee compensation), conversion (manufacturing), and revenue (sales/collection). By providing students with a perspective on grouping organizational events into logical categories, the REA Ontology helps students focus on not only the interrelatedness of different processes, but also on how processes are consistent across organizations.

The REA Enterprise Ontology is touted as a philosophy that frames organizational information needs as a set of basic enterprise components. It can be used to track the way in which resources are traced through enterprise-specific business functions, how business processes are interrelated and how they contribute to value, how specific tasks affect completion of economic events, and how business processes are controlled (Geerts, McCarthy, and Rockwell 1996). The REA Ontology defines a business process as an exchange as well as the tasks needed to execute that exchange (Geerts and McCarthy 2000). This definition is similar to that given by Hammer and Champy (1993, 53) that a process is "a collection of activities that takes one or more kinds of inputs and creates an output that is of value to the customer." REA process diagrams can be used to show the high-level flows of economic resources in the enterprise, related to both the economic events and collaborations between the agents that participate in the exchanges. REA process diagrams are sometimes referred to as value-chain diagrams. The resource flows between processes in these diagrams represent the collective unbalanced stock-flows, consumed and produced by the events belonging to given processes. An REA enterprise script depicts the actual configuration of processes within a firm (Geerts and McCarthy 1999). An REA enterprise script is a series of processes, consisting of exchanges, where collaborations between agents are realized with groups of ordered tasks, called recipes

(ECIMF 2003). The basic framework can readily generate an enterprise set of specifications that can be represented in a generalized REA model whose events can be further decomposed into specific tasks (Geerts and McCarthy 2001).

The REA Ontology, as represented in Dunn, et al. (2005), presents a Value System in which there are four primary stakeholders: customers, suppliers, investors/creditors, and employees. The next level, or the value chain, consists of five primary processes as noted earlier: financing, acquisition/payment, payroll (employee compensation), conversion (manufacturing), and revenue (sales/collection). Finally, each of those can be broken down into specific business processes, which can in turn be decomposed into constituent tasks. See Figures 5 and 6 for example diagrams of the Value System and Value Chain. The next step in evolving the REA Ontology model would require the development of scripts for the individual processes that comprise each function illustrated in Figure 6. These steps are outlined in Table 1.

One important feature of the REA Ontology is the inclusion of domain-specific rules intended to help structure economic phenomena. Geerts and McCarthy (2000) note that the following two rules illustrate these structuring capabilities:

1. The duality relationship must be enforced. This stipulation forces analysts and designers to consider explicitly the causal links between events and, as a consequence, the links between resources.
2. An economic resource requires that both an inflow event and an outflow event be specified. This requirement insures that resources are purposely acquired and that exchanges are combined into an enterprise script.

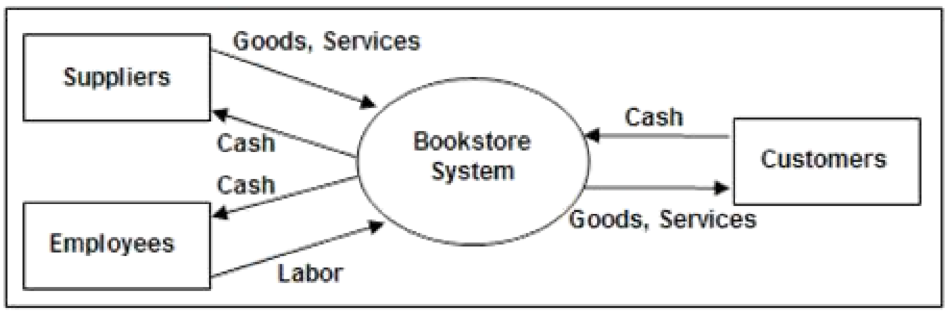

Figure 5. Bookstore REA Value System Level Model

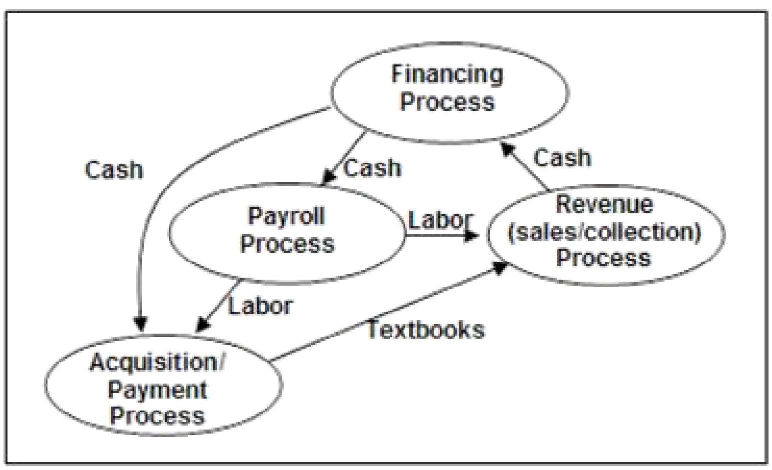

Figure 6. Bookstore REA Value Chain Model

A COMPARISON OF THE DFD APPROACH TO THE REA ONTOLOGY

Although REA was originally developed to provide a generalized framework for AIS in a database environment (McCarthy 1982), it has evolved to be more comprehensive. Specifically, REA has been discussed as a method for enterprise information systems to capture all business processes and events (Denna et al. 1987). Individual business events represent the building blocks for economic events and are defined as “any strategically significant business activity management wants to plan, control, and/or evaluate” (Denna et al. 1987, 356).

DFD Level	System	Conceptual	Model
Context	Bookstore System	Context Level – One System	Book Store System Indicated by inputs and outputs from/to Stakeholders (Students, University, Vendors, Employees)
0	Major Functions	Purchase Sub-System Sales Sub-System Return Sub-System	Inputs from Stakeholders, Outputs to Stakeholders, Data Stores, Consistency of Inputs and Outputs with Prior Level = Balancing
1	Major Functions of Each Process	Receipt of Books Needed Purchase Orders Returns Payments Receipt of Book Orders Sales of Books Book Returns	Each Major function represented in input – process – output model. After initial external trigger, inputs may be prior outputs of other processes with temporal or state triggers Input flows can be split into multiple process or data stores inputs. Multiple outputs can represent a single output from system
2 .. N	Major Functions of Each Prior Process	(For Sales of Books) Create Sale (Check Orders) Input Student Id Input Selected Books Calculate Totals (Tax) Input Payment Type Print Receipt Receive Cash	Each Major Function of Prior Process represented in General Systems (IPO) Model If not represented earlier, specific data stores required (can be aggregated at a prior level) If process steps cannot be clearly stated, decompose one more time…..

Table 1. Representation of Levels and University System/Book Store

While the similarities between the REA model and entity-relationship diagrams (ERDs) have been pointed out in other manuscripts (Trimmer et al. 2002; Trimmer and Parker 2004; Parker, LeRouge and Trimmer 2005), no manuscripts acknowledge or recognize the similarities between the REA Ontology and DFDs. By comparing Figures 5 and 6 with Figures 1 and 2, similarities between the two approaches become apparent. The initial diagram in a DFD is the context diagram, which is quite similar to the Value System diagram in the REA Ontology. Each consists of a central system that interacts with various external entities. The REA Ontology generally refers to these external entities as stakeholders. Although the stakeholders are specified explicitly as customers, suppliers, investors/creditors, and employees, the ontology is extensible and allows additional stakeholders or the elimination of unused ones. An ontology's usefulness is highly dependent on its extensibility. Extensibility means that new concepts can be incorporated without altering the ontological foundations. Extensibility is particularly important in dynamic environments like business (Geerts and McCarthy 2000).

The next level on the data flow diagram is Level 0, which represents a functional decomposition of the context diagram. As explained above, Level 0 depicts the primary processes that work together to accomplish the overall system specified in the Context Diagram. Similarly, in the REA Ontology the Value Chain diagram depicts the primary processes required by the overall system. Again they are specifically named–financing, acquisition/payment, payroll, conversion, and revenue–but the diagram can be extended to incorporate additional processes if necessary.

Level 0 processes on the DFD can be further broken down into Level 1 diagrams to show an increasing amount of detail, and Level 1 processes can be decomposed into Level 2 diagrams, and so forth. Likewise, the Value Chain diagram in the REA Ontology can be further reduced to more detailed diagrams of its component business processes. At some point each graphical depiction expresses sufficient detail; at the elementary processes for DFDs and at individual tasks in the REA Ontology. Table 2 provides a tabular comparison of the two modeling approaches.

The script in Figure 7 provides a more detailed representation of Table 1's depiction of the DFD levels involved in a university book store. The context diagram of a DFD would show a single system representing the book store. This is represented in Figure 1, which shows the renaming of the book store system to the Textbook Inventory System. This diagram corresponds to the REA Value System represented in Figure 5. Figure 2, the Level 0 diagram for the Textbook Inventory System, is similar to Figure 6, the REA Value Chain view. The final diagram, Figure 3, represents the Level 1 diagram for the Textbook Inventory System. Its processes correspond to the detail represented in the script in Figure 7.

Model Level	REA Ontology	DFD
Top	Value System	Context Level
Decomposition 1	Value Chain	Level 0 (Functional Decomposition)
Decomposition 2	Business Process	Level 1
Decomposition 3..N	Task	Level 2 … N (Elementary Process)

Table 2. Comparison of the REA Ontology to DFDs.

The purpose of the Textbook Inventory system at an independently owned campus bookstore is to supply textbooks to students for classes at the university. The university's academic departments submit initial data about courses, instructors, textbooks, and projected enrollments to the University Registration System in a course master list. This information is provided to the bookstore by the University. A bookstore employee generates a purchase order, which is sent to publishing companies supplying textbooks. Book orders arrive at the bookstore accompanied by a packing slip, which is checked and verified by employees in the receiving department. Students fill out a book request that includes course information and submit this to the bookstore. This request is filled by an employee, and the student pays the cashier for the books and is given a sales receipt. Should the student drop the course within the first ten days of classes, provided the books have not been 'marked', the bookstore will accept returns from the student and refund their payment (they must have their original receipt). Near the end of the semester, the bookstore accounts payable clerk pays for all textbooks sold, and has the option of returning all unsold textbooks back to the publishing companies.

Figure 7 Bookstore REA Script

USING THE REA ONTOLOGY IN THE IS EDUCATIONAL PROCESS

The REA model incorporates contextual teaching and learning. Because modeling is presented in terms of concepts already familiar to the student, e.g., the duality of the accounting transaction, students can immediately see the relevance of their prior knowledge and are more likely to understand the concepts because they can be related to something familiar (Crawford 2001). Even students who have not taken an accounting course have experience with basic business transactions; and as such, even those without explicit exposure to REA have had implicit exposure to the concepts upon which it is based, allowing them to relate the model to a familiar activity. Contextual learning theory asserts that learning occurs when students process new information or knowledge in such a way that it makes sense to them in their own frames of reference. This approach assumes that the mind naturally seeks meaning in context—that is, in relation to the person's current environment—and that it does so by searching for relationships that make sense and appear useful (Texas Collaborative for Teaching Excellence 2002). The contextual learning factor combined with active learning strategies, helps the students to understand and retain process modeling concepts that are sometimes unclear when traditional modeling approaches are used.

REA lends itself to adaptation and can be revised to address further complexity (Weber 1986). Because of its broad conceptual nature and definitions, REA is a highly rule-based, yet flexible approach. It allows students to build their mental models and achieve modeling tasks in an efficient and effective manner as they link high-level conceptual representations of business goals to models generally accepted for both logical and physical modeling. Dunn and Grabski (1997) provide empirical support for REA's superiority in terms of accuracy of task and user satisfaction.

Aside from potential gains in teaching effectiveness and efficiency, the REA approach also has the benefit of being consistent with a general undergraduate business curriculum that emphasizes strategy. REA can also serve as a method to assist in identifying elements on the Value Chain (Porter and Millar 1985) and converting them into readily understood models (Hollander et al. 2000). Because REA initially focuses on economic events, it provides competition for the purely economic and incumbent debit-credit model. IS curricula are challenged with equipping students with the ability to view technology from a strategic perspective. In business contexts, a strategic approach to process modeling contributes to the on-going support for necessary functions and potential competitive advantage. Using the REA to supplement the teaching of traditional data flow modeling makes the entire modeling process more clear to the student.

Teaching the REA Ontology for Process Modeling

The steps for identifying elements in the REA approach are similar to the steps that are followed when developing a DFD. The designer must first determine the scope of the system to be modeled, and then must indicate the flows to and from the stakeholders. The stakeholders can be assigned more explicit labels than those provided by the ontology. In a student bookstore, for example, the customer stakeholder is replaced by a student stakeholder. As the Value System is developed, the designer must be sure to satisfy the duality requirement, as well provide economic events with both inflows and outflows. When the Value System is exploded to arrive at the Value Chain, the designer must consider how the primary processes—financing, payment, payroll, conversion, and sales (Dunn et al. 2005) —are incorporated into the model. Again, care must be taken to provide duality and the proper inflows and outflows. As the diagram is further decomposed, the business processes that are involved in the primary functions are modeled, as are the flows between them. This functional decomposition continues until individual tasks are depicted on the diagram.

The REA Ontology allows students to gain an understanding of how the big pieces of the systems puzzle fit together, helping to eliminate the 'siloed system' mentality. One advantage of this approach is that it incorporates key nonfinancial/noneconomic data that may be overlooked in DFD modeling. Linking the REA Ontology to modeling techniques that are supported by computer-aided software engineering (CASE) tools, and that eventually lead to quality applications, also provides relevance for the comprehension of the difficult conceptualization of an organization and its processes.

CASE tools have been developed to assist in the design of an REA Ontology. CREASY requires designers to view enterprise models as an enterprise script of economic exchanges (Geerts and McCarthy 1992). In the REACH tool, three different types of knowledge are used for the integration of different conceptualizations, including first-order principles of the REA model, heuristic guidance of implementation compromises based on object pattern matches, and reconstructive expertise for prototypical models (Rockwell 1992; Rockwell and McCarthy 1999). The first-order principles correspond to the REA primitives, while the two other types of knowledge correspond with best practices and experiences for the implementation of REA patterns (Geerts and McCarthy 2000).

CONCLUSION

Process modeling is an important IS skill taught in an IS curriculum at most universities. However, the current method of teaching process modeling can be supplemented by an REA Ontology approach that may be easier for students to grasp.

REA is a highly conceptual approach for helping students think about modeling, and enjoys widespread use in AIS programs within the United States, as well as other countries (University of Sydney 2004). The REA Ontology provides a framework for understanding business processes, and helps to direct the modeler's initial focus toward understanding the processes. The ability to represent parts of the model as scripts or narratives helps enable the student to see both the general and specific issues in a given situation. The model is linked to value chain concepts, as well as both data and process modeling. In essence, the REA Ontology can serve as a guide or method on how to approach data flow modeling. We believe that this perspective is beneficial in linking business and technical concepts, thereby enhancing our students' future career performance.

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