A CASE STUDY IN HOW THEORETICAL CONCEPTS UNDERLYING INTEGRATED LEARNING OBJECT-BASED INSTRUCTIONAL SYSTEMS TRANSLATE INTO EFFECTIVE PRACTICE

by

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A dissertation submitted to the Department of Instructional and
Performance Technology
College of Professional Studies
The University of West Florida
In partial fulfillment of the requirements for the degree of
Doctor of Education

2003

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ACKNOWLEDGMENTS

Writing a dissertation, no matter whose name appears on the title page, is a collaborative activity. My supporters fall into three slightly overlapping groups.

My committee members, Drs. Janet Pilcher, Lee Droegemueller, Karen Rasmussen, and especially my chair, Dr. Pamela Northrup, deserve a special note of appreciation for not only enduring this marathon, but also for guiding me through critical decision points and letting me think they were my ideas.

The QuickScience™ development team, especially again, Dr. Pamela Northrup, Dr. Karen Rasmussen, and Mr. Kelsey Henderson, merit recognition for not only good naturedly enduring the close scrutiny of this study, but also more importantly for being fervently engaged in using technology to help people perform better in serving the needs of our society. Their profound thought, stimulating discourse and creative insight are the intellectual oxygen that feed my continuing enthusiasm for this field.

My family deserves the highest recognition. My parents, Gloria and Carl Dawson, have always supported my education with great enthusiasm, especially my father, who passed before the completion of this study. My children, Bryan, Lauren, and Haley, have paid the price I feel most acutely, the time spent on this work instead of with them. Most importantly of all, my wife, Susan, has earned, as has no other, the real credit for completion of this study. Without her support, faith, sacrifice, and love, I would have never begun this enterprise, let alone pursued it to completion. I extend my most heartfelt thanks to all.

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ABSTRACT

A CASE STUDY IN HOW THEORETICAL CONCEPTS UNDERLYING INTEGRATED LEARNING OBJECT-BASED INSTRUCTIONAL SYSTEMS TRANSLATE INTO EFFECTIVE PRACTICE

David Bruce Dawson

The purpose of this study was to determine how theoretical concepts underlying an implementation of an integrated learning object-based instructional system translate into effective practice. Underlying theoretical concepts are grouped into the 5 dimensions of a grounded learning systems design model: psychological, pedagogical, technological, cultural, and pragmatic. These 5 dimensions serve as a framework for examining a case of integrated learning object-based instructional systems development. Such systems possess characteristics, features, and processes that embody varying interpretations of those theoretical foundations while also reflecting the contexts within which they are developed. Using documentary evidence, structured interviews with key development team members, and critical analyses of main interface screen shots, the framework is used to characterize the links between those practical expressions and the underlying theoretical concepts of such systems.

CHAPTER I

INTRODUCTION

The accelerated pace of change in industry and education has motivated some institutions to adopt different approaches to the design and development of instruction. Among those changes is the growing number of institutions adopting distributed learning models (Farrington & Yoshida, 2000). Additionally, leaders of those institutions adopting distributed learning models are recognizing that their approaches to distributed learning must be programmatic in order to provide meaningful access to their service populations effectively (Farrington, 1999).

A number of technologies, such as Web-based instruction, aid in the implementation of distributed learning models. Additional supporting technologies such as dynamic database middle ware support Web-based instruction (but are less apparent to end users). These offer potential efficiency, flexibility, and scalability to developers of distributed learning systems. The concept of learning objects as sharable, reusable resources that can be used dynamically to populate Web-based frameworks with learning content is an example of such a technology. While practitioners in the field of computer science have a lengthy history of employing knowledge object-based algorithms in the development of expert systems, the application of the concept to the broader field of learning has been a relatively recent development. The sharable content object reference model, or SCORM, and the Cisco reusable learning object model (Barritt & Lewis, 2001) are examples of learning object theory put into practice.

While attention is often focused upon the technological aspects of distributed learning model implementations, the change brought about in the learning organization by the adoption of such a model can be more far-reaching than that represented by the technology alone. One common example of such change related to the adoption of a distributed learning model is an associated distribution of the responsibility for the character of the learning experience to the practitioners tasked with delivering it. Teaching strategies, content selection and organization, and validation of content for alignment to standards are examples of elements affecting the character of the learning experience that are often provided to the teacher in distributed learning environments. The distribution of responsibility for these elements, however, is not necessarily commensurately supported with professional development in these areas.

The Educational Problem

Web-based delivery models are common choices for institutions seeking to provide instructional and training programs via distributed learning technologies and are often embraced with a certain degree of urgency. Demand for the production of Web-based instructional programs is great, but budget inadequacies for their production threaten their timeliness for consumption (Hawkins, 1999).

The production rate problem for a distributed learning program is compounded by the unique demands of Web-based instruction, particularly if developers choose conscientiously to follow theory-grounded instructional design principles. This design model addresses the alignment of psychological, pedagogical, technical, cultural, and pragmatic dimensions of the program with corresponding fundamental theoretical concepts to ensure that developers have done everything possible to maximize the effectiveness of the instruction (Hannafin, Hannafin, Land, & Oliver, 1997).

The demand for higher Web-based learning content output in response to market demand, increasing expectations for educator performance as evidenced by such things as standardized testing, and tightening educator professional development budgets combine to present learning organizations a serious challenge. The challenge is to provide quickly effective Web-based learning opportunities aligned with standards or institutional objectives with a minimum investment in professional development related to their application.

Educational Significance of This Study

The nature of developing and implementing an instructional tool based upon learning object technology and reflecting the principles of grounded instructional design is of particular significance to the field of education for two reasons. First, the simplicity and efficiency of the instructional development process that learning object technology affords educators can be an attractive solution to the problem of producing content at satisfactory rates that many organizations experience when faced with producing Web-based instruction on a large scale. Second, the incorporation of grounded instructional design principles into the integrated learning object-based instructional system itself addresses the concerns of many educators regarding the quality and efficacy of Web-based instruction. Grounded instructional design offers educators established theoretical principles and practices integrated into a systematic approach to the development of instruction. The application of grounded instructional design through an implementation of reusable learning object technology provides a uniquely rich area for exploration.

The Learning Object Metadata Working Group of the Institute of Electrical and Electronics Engineers, Inc. (IEEE, 2001) Learning Technology Standards Committee (LTSC) provides this definition of a learning object:

> Learning objects are defined here as any entity, digital or nondigital, which can be used, reused, or referenced during technology supported learning. Examples of technology supported learning include computer-based training systems, interactive learning environments, intelligent computer-aided instruction systems, distance learning systems, and collaborative learning environments. Examples of learning objects include multimedia content, instructional content, learning objectives, instructional software and software tools, and persons, organizations, or events referenced during technology supported learning. (¶ 1)

Most approaches to the development of tools using learning objects reflect the focus of the United States' federal government's Advanced Distributed Learning initiative, which is directed toward the technological specifications and metadata standards that enable the reusability and transportability of learning objects across applications (Singh, 2000). Less attention is generally directed toward the integration of sound instructional design principles, particularly grounded instructional design theory, in the development of design tools for object-based learning systems (Wiley, 2002).

An examination of how the concepts underlying learning object-based instructional design tools are implemented may yield insights useful to other institutions contemplating adoption of these practices. Such insights may also be useful to developers in refining and adapting such design tools. Finally, such insights may illuminate critical intersections of theory and practice in this field for researchers.

Purpose and Approach

Determining how theoretical concepts underlying an implementation of an integrated learning object-based instructional system translate into effective practice was the purpose of this study. If the underlying theoretical concepts are grouped into the five dimensions of Hannafin et al.'s (1997) grounded learning systems design model–(a) psychological, (b) pedagogical, (c) technological, (d) cultural, and (e) pragmatic–these five dimensions might then constitute a framework for examining cases of integrated learning object-based instructional systems development. Such systems possess characteristics, features, and processes that embody varying interpretations of those theoretical foundations and also reflect the contexts within which they are developed. The framework may be used to characterize the links between those practical expressions and the underlying theoretical concepts of such systems.

The principal research question for the study was as follows: How do theoretical concepts underlying integrated learning object-based instructional design tools translate into effective practice? Five subquestions served as the foundation for initial grouping:

1. What psychological concepts are important to learning object-based instructional design tools, and how are they reflected in practice?
2. What pedagogical concepts are important to learning object-based instructional design tools, and how are they reflected in practice?

3. What technological concepts are important to learning object-based instructional design tools, and how are they reflected in practice?
4. What cultural concepts are important to learning object-based instructional design tools, and how are they reflected in practice?
5. What pragmatic issues are important to learning object-based instructional design tools, and how are they reflected in practice?

The psychological theoretical framework through which this study examined integrated learning object-based instructional systems traces a path from Piaget (1952) through Ausubel (1968). The path followed Piaget’s modes of learning as ongoing processes of cognitive adaptation to the environment through Ausubel's position that knowledge is hierarchically organized in cognitive structure and that the properties of the relationships between knowledge elements are critical to the usefulness of that knowledge to the learner. The holistic approach of theorists such as Vygotsky (1934/1962) who provide a sense of continuity and relational dimension to the concept of cognitive structure serves as the basis for later schema theorists West, Farmer and Wolff (1991) whose pedagogical strategies are aligned with those concepts.

The dimension of technological theory is represented through organizing strategies, grouped through a higher level framework of actions as Merrill (2000) demonstrates, to simplify and focus the design requirements for instructional objectives. These methods are suitable for application in learning object technologies exemplified in the Cisco reusable learning object model and are derived from similar work in the development of expert systems and knowledge base problem-solving tools (Barritt & Lewis, 2001).

The cultural aspects of implementing and integrating innovative practices represented by integrated learning object-based instructional systems are addressed through the work of observers of change, such as Rogers (1995), who provide a model for understanding and navigating the change processes spawned by innovation.

Finally, Farrington and Yoshida (2000) characterize the pragmatic dimension underpinning the development of learning object-based instructional design tools. They describe the shift of focus in learning institutions toward nimbler infrastructures and identify the increased pressure on those institutions, as Hawkins (1999) notes, to be more responsive to market demands.

A single case study design was used to examine an implementation of an integrated learning object-based instructional system. The process and product were examined through the framework of grounded learning systems design theory and documented for analysis through (a) the triangulation of participant observation, (b) document reviews, (c) product reviews, and (d) interviews with design teams.

The participants in this study included the members of the design team involved in the production of an integrated learning object-based instructional system. The design team as a whole served as the unit of analysis for the study. Each key team member was classified according to his or her role in the development and execution of the project and interviewed for personal insight into the project's development. It is, however, the collective work representing the interactions among the entire group that accounts for the character of the project's expression of underlying theoretical principles.

The University of West Florida served as the host institution for the federal grant supporting the project, the development team, and the QuickScience™ technical infrastructure. Within the University's College of Professional Studies, the Innovative Technology Center provided the administrative home for the QuickScience™ project as well as the physical setting for most of its development and implementation activities.

Three protocols were employed to aid in the collection of data from each of three classes of sources. The protocols were all based upon Hannafin et al.'s (1997) five dimensions of grounded instructional design: (a) psychological, (b) pedagogical, (c) technological, (d) cultural, and (e) pragmatic.

Participant Observation

Participant observation data for the study were derived from the notes and anecdotal recollections of the investigator. These materials addressed the period of time the project had been in development.

Collection of Artifacts

Materials used for this study included the integrated instructional system itself. The tool is called QuickScience™. It was examined in accordance with an evaluation protocol to identify features that reflect the five dimensions of grounded instructional design: (a) psychological, (b) pedagogical, (c) technological, (d) cultural, and (e) pragmatic. Additional materials included (a) concept proposal documents, (b) design documents, (c) project reports, and (d) other documents that surfaced to help characterize the theoretical underpinnings of the project.

Unstructured Interviews

Fifteen main interview questions grouped along the five grounded dimensions (psychological, pedagogical, technological, cultural, and pragmatic) served as the basis for the collection of data from interviews with the principal QuickScience™ team members. Transcripts of subject interviews and any e-mail correspondence related to requests for clarification or amplification of responses served as material for analysis.

Data Analysis

The data analyzed for the study came from examination of the integrated learning object-based instructional system itself, examination of the collected documents, and from transcripts of the personal interviews and correspondence with selected members of the QuickScience™ project team. These data were supported by additional observations and recollections of the researcher in the role of participant observer. The protocols for collection of the three types of data were designed to reflect the five dimensions of grounded instructional design theory that serve as the framework for analysis of the data collected.

The analysis of the collected data also included initial grouping of data elements along the five dimensions of Hannafin et al.'s (1997) grounded learning systems design theory. These dimensions provided the initial framework for organizing the data.

By associating data from the collection protocols with base-line concepts derived from the literature, important relationships or thematic affinities among the responses and the theoretical framework may emerge. Themes and patterns developed through this process served as tools to refine the emergent constructs into a coherent theory that was aligned with the practices and products represented by the case (Creswell, 1998).

CHAPTER II

REVIEW OF THE LITERATURE

Introduction

The intersection of interests expressed through a theory-grounded, reusable learning object-based instructional design tool draws a number of diverse disciplines together to focus on the same issue. The issue is the demand among learning institutions for an efficient means of producing effective instructional materials. The production means must integrate support for the designer into the use of the tool itself and provide both flexibility in application and the capacity to leverage materials produced to their maximum effect.

Two concepts bind these interests together and serve as the framework through which an investigation might proceed. The first concept is the reusable learning object as it is expressed in the work of Barritt and Lewis (2001) and Wiley (2002). They provide a working definition for the reusable learning object, describe its morphology, and outline a rationale for its application.

Reusable Learning Objects

Historical Perspective

Although Wiley (2002) surveys a number of current definitions for learning objects, he proposes a highly simplified alternative based on the Institute of Electrical and Electronics Engineers, Inc. (IEEE) Learning Technology Standards Committee's definition: "any digital resource that can be reused to support learning" (p.7). Wiley's definition essentially describes reusable digital resources while rejecting nondigital, nonreusable objects. The definition also focuses on the purposeful, supportive role the object plays in learning, not simply its usability in learning activity (Wiley).

Wiley (2002) addresses what he characterizes as a lack of concern with the instructional design implications of learning objects among those involved in the development and facilitation of learning object technology. He notes that the Learning Objects Metadata Working Group standard fails to include any instructional design information in its specifications for metadata, and other standards bodies (as well as vendors) offer as a valuable attribute the instructional theory neutral character of their products (Wiley). Wiley also proposes that the Legoes analogy commonly used to describe learning objects has been harmful. The analogy compares units of knowledge with the interchangeable modules of the children's construction toy in which modules may be recombined, resequenced, or configured in any number of combinations. The implication is that any learning object can be combined with any other in any sequence by anyone to create instruction. Wiley proposes that if the organizations show no interest in an instructionally grounded approach to learning object sequencing, there is little hope that the teacher using the material will have any motivation to do otherwise.

Another issue linking learning objects and instructional design is that of granularity, which Wiley (2002) characterizes as the most difficult problem facing designers of learning objects. As learning objects grow in size, their reusability becomes increasingly problematic, but the expense associated with the documentation and categorization of objects as small as individual images or paragraphs of text quickly becomes prohibitive for most applications, even taking reuse into account (Wiley). The scope of an object, or how much or how little to include in it, is another decision that Wiley insists must not be made without instructionally grounded, principled deliberation.

Learning Object Taxonomy

Wiley (2002) suggests the terms *granularity* and *combination* are analogous to the terms with which instructional designers are more familiar, *scope* and *sequence*, to illustrate how grounded instructional design is critical to the success of learning object technology. He proposes another metaphor for learning objects: the atom which serves as a theoretical workbench for thought about learning object applications (Wiley). Unlike the Lego analogy

1. Not every atom is combinable with every other atom.
2. Atoms can only be assembled in certain structures prescribed by their own internal structure.
3. Some training is required to assemble atoms. (Wiley, p. 17)

A taxonomy of variables to identify and organize them in relevant ways is a construct that Wiley (2002) proposes is necessary to any instructional design theory. He suggests that users of learning objects for instruction cannot easily benefit from the application of any instructional design theory without the adoption of a taxonomy that addresses the distinguishing characteristics of different learning object types (Wiley).

Wiley (2002) suggests that all learning objects possess a set of qualities. The degree to which an object possesses each quality cumulatively differentiates one object from another (Wiley). Wiley describes eight learning object characteristics that are both sufficiently universal and measurable to use as the basis for a taxonomy of learning object types:

1. Number of elements combined. Describes the number of individual elements combined in order to make the learning object.
2. Type of objects contained. Describes the type of learning objects that may be combined to form a new learning object.
3. Reusable component objects. Describes whether or not a learning object's components may be individually accessed and reused in new learning contexts.
4. Common function. Describes the manner in which the learning object is generally used.
5. Extra-object dependence. Describes whether the learning object needs information about learning objects other than itself.
6. Type of logic contained in object. Describes the common function of algorithms and procedures within the learning object.
7. Potential for intercontextual reuse. Describes the number of different learning contexts in which the learning object might be used, that is, the object's potential for reuse in different content areas or domains.

8. Potential for intracontextual reuse. Describes the number of times the learning object might be reused within the same content area or domain.

Wiley (2002) uses the eight learning object characteristics to define five distinct learning object types:

1. Fundamental. A single individual resource uncombined with any other.
2. Combined-closed. A small number of digital resources combined at design time to create a single-purpose object whose components are no longer individually accessible for reuse outside the object itself.
3. Combined-open. A collection of digital resources assembled dynamically at the time of use and whose individual components are accessible for reuse. The individual components may be combined-closed or fundamental object types.
4. Generative-presentation. Logic and structure for combining or generating lower level learning objects. These objects have high intracontextual reusability, but they have low intercontextual reusability.
5. Generative-instructional. Logic and structure for combining learning objects of all types and evaluating learner interaction with those objects. These learning object types are high in both intra and intercontextual reusability.

Three components constitute a successful learning object implementation according to Wiley (2002): (a) an instructional design theory, (b) a learning object taxonomy, and (c) prescriptive linking material to connect theory to taxonomy.

The Cisco Reusable Learning Object Model

While Wiley (2002) approaches the concept of reusable learning objects from the perspective of taxonomically describing features of reflecting instructional design theory, Barritt and Lewis (2001) address the concept of reusable learning objects from the perspective of production and systems management. Barritt and Lewis suggest that the demands placed on modern training organizations require a move away from the development of static, custom-designed, single-purpose courses to “reusable, granular objects that can be written independently of a delivery medium and accessed dynamically through a database” (Barritt & Lewis, p. 4). They proposed as a solution the system developed by their Internet Learning Solutions Group at Cisco Systems. Barritt and Lewis identify the system as the reusable learning object (RLO) strategy.

Advantages of Reusable Learning Object Use

In discussing the benefits of the RLO model for instructional designers, Barritt and Lewis (2001) identify seven specific advantages the system has over traditional design methods:

1. The model facilitates the use of development and delivery templates to ensure consistency throughout a system.
2. Templates improve the efficiency of instructional development and help ensure effectiveness.
3. Metadata on objects allow them to be easily discovered and reused.
4. Any object is available for use in any combination.

5. Resources of varying granularity may be stored and reused in any combination.
6. Since presentation is independent of content, authors may focus on instructional requirements without concern for format or stylistic limitations.
7. The database of objects may be brought into application through any number of delivery methods and for multiple purposes.

Barritt and Lewis (2001) also identify five specific advantages of the RLO model for the delivery of instruction to learners:

1. Templates and stylesheets ensure that the learner is presented a consistent interface that facilitates predictable tool performance across instructional units.
2. The objects may serve not only as instructional units, but also as support for the performance of the learner in the context of their job.
3. The learning style of the learner can be accommodated through customization of the interface.
4. The unique instructional or performance requirements of the individual can easily be addressed through individualized learning paths.
5. The learner may access a range of object types, from smallest and most specific to largest and most generalized, depending on the requirement.

Reusable Information Objects

The structure of the model described by Barritt and Lewis (2001) begins with the fundamental unit identified as a Reusable Information Object (RIO). Each RIO focuses on a single objective and is composed of content items, practice items, and assessment items. Barritt and Lewis also specify that the RIO must also contain metadata, including,

1. Title objective and type.
2. Job function and job task.
3. Author name and owner name.
4. Creation date, publish [sic] date, and expiration date.
5. Prerequisites. (p. 22)

Furthermore, each RIO must be assigned a cognitive level value in the object's metadata that identifies how learners will remember or use the information contained in the RIO (Barritt & Lewis, 2001). The cognitive level scale developed by Clark (1989) and employed in Barritt and Lewis' model is a hybrid of Bloom and Krathwohl's (1994) taxonomy and Merrill's (1983) component display theory. Where Merrill divides cognitive level into two parts–that which must be remembered or that which must be used–Bloom and Krathwohl divide it into six levels: (a) knowledge, (b) comprehension, (c) application, (d) analysis, (e) synthesis, and (f) evaluation (as cited in Barritt & Lewis). Barritt and Lewis require that all RIOs be tagged either *remember* or *use*. Assigning the remember tag for cognitive level automatically means that it corresponds to Bloom and Krathwohl's knowledge level, but if the use tag is assigned, a sublevel designation from one of the top five levels from Bloom and Krathwohl is required. This subdesignation would be (a) comprehension, (b) application, (c) analysis, (d) synthesis, or (e) evaluation (Barritt & Lewis).

RIO Content

Content is specified to be a single concept, fact, procedure, process, or principle in Barritt and Lewis' (2001) model. Barritt and Lewis provide specifications for each content type that describe (a) when that type of RIO is to be used, (b) where it should be placed in the sequence of RIOs in a RLO, (c) its structure, (d) examples of things that would be taught with that type of RIO, and (e) how to identify content that is appropriate for that type of RIO.

The content component of a concept RIO for example, contains (a) an introduction; (b) important facts if required; (c) a definition; (d) an example and, usually, an example that does not meet the object's criteria; and (e) an optional analogy and instructor's notes (Barritt & Lewis, 2001). A fact RIO, on the other hand, will only contain an introduction, the fact itself, and perhaps some instructor's notes (Barritt & Lewis). The other RIO content types become a little more complex. The content type component for a procedure contains an introduction, perhaps some facts, and either a procedure table, a decision table, or a combined table, in addition to a possible demonstration and instructor's notes (Barritt & Lewis). Likewise, a process RIO includes an introduction, possibly some facts, and either a staged table, block diagram, or cycle chart, and, possibly, some instructor's notes (Barritt & Lewis). Finally, Barritt and Lewis describe a principle content type RIO as containing an introduction, possibly some facts, possibly a principle statement, guidelines for applying the principle, an example, possibly an example that does not meet the object's criteria, possibly an analogy, and instructor's notes.

Practice and Assessment

Practice items are reinforcement activities that apply the RIO’s content (Barritt & Lewis, 2001). They do not usually contribute to the overall assessment of the learner’s mastery of the concept, but usually include feedback mechanisms to reinforce the important elements of the content in response to the learner’s performance. Practice items may include (a) matching, (b) multiple choice, (c) true or false test items, (d) text entry, (e) simulations, (f) case studies, and (g) hands-on labs (Barritt & Lewis).

Assessment items measure the learner’s mastery of the RIO’s learning objective (Barritt & Lewis, 2001). They may take the form of questions or any measurable activity, but they must both match the learning objective of the RIO and measure the appropriate cognitive level designated for the RIO (Barritt & Lewis).

Assembly of RLOs

The larger instructional unit composed of RIOs, the RLO is based on “a single learning objective derived from a specific job task” (Barritt & Lewis, 2001, p. 7). Barritt and Lewis’ RLO is composed of an overview, between five and nine RIOs, and a summary.

The overview provides the learner an advanced organizer that includes (a) an introduction, (b) an explanation of the importance of the information contained in the RLO, (c) the objectives of the RLO, (d) a list of any prerequisites that may be required before using the RLO, and (e) an outline of the RLO (Barritt & Lewis, 2001). It may also include a job-based scenario as a model for how the information in the RLO may be applied (Barritt & Lewis).

The RLO summary brings the RLO to a close, provides a review of the material covered in the RIOs, and serves as a transition between the RIOs and the assessment section composed of assessment items from each RIO in the RLO (Barritt & Lewis, 2001). The summary may also provide information about the next steps the learner must follow and point to additional resources the learner might explore (Barritt & Lewis).

The Model

Hannafin et al. (1997) suggest that new interest in constructivist learning theories presents opportunities for the evolution of instructional design theory. They propose that new opportunities are important to the field because of the unsatisfactory disconnection between theoretical prescriptions for instructional design and actual design practices, particularly in the context of technology-enhanced learning environments (Hannafin et al.).

Hannafin et al. (1997) respond to the mismatch between theory and practice in instructional design by proposing an approach called grounded learning systems design, which they define as “the systematic implementation of processes and procedures that are rooted in established theory and research in human learning” (p. 102). A grounded learning systems design does not provide designers with explicit, algorithmic steps that are to be rigidly applied. Instead, the design processes and procedures are guided by heuristics that incorporate a number of approaches and perspectives reflecting the proposition that learning is not a unitary concept (Hannafin et al.).

Grounded Learning System Design Requirements

Hannafin et al. (1997) suggest that grounded learning systems design seeks the articulation of and alignment among underlying principles supporting a number of theories and methodologies. They propose that such a design system must meet four conditions:

1. The design must be based on a defensible theoretical framework that can be articulated clearly and differentiated from other perspectives.
2. The design methods must be consistent with the outcomes of research that test, validate, or extend the underlying theories.
3. The design methods must be applicable to more than a single specific problem or setting.
4. The validation of grounded designs and frameworks is iterative and the theoretical frameworks are refined through successive implementations.

Establishing the Link Between Assumptions and Methods

While many instructional design practices produce good results, and many designers employ successful approaches to instructional design that they have developed through experience, Hannafin et al. (1997) suggest that many designers can neither explain exactly why such practices are successful nor accurately predict their effectiveness in other similar applications. They propose that developmental approaches employing grounded learning systems design consistently link given foundations and assumptions to specific instructional methods in a defensible theoretical framework rooted in related research (Hannafin et al.). An important feature of the position Hannafin et al. hold in supporting grounded learning systems design is that it is possible for many approaches and methods to coexist, as long as they are rooted in corresponding theoretical foundations. The focus is on the grounded nature of the approaches, not on which epistemology is inherently correct (Hannafin et al.).

The Five-Dimensional Framework

Hannafin and Land (1997) propose that “Learning environments are rooted in five foundations: Psychological, pedagogical, technological, cultural, and pragmatic” (p. 172). This is valuable to the study because it provides a framework of recognized, familiar classes of concepts through which designers may systematically characterize the features of a learning system.

The Common Path of Psychological and Instructional Theory

Beliefs about how knowledge is acquired and used are fundamental to learning environment designs (Hannafin & Land, 1997). Such beliefs form the psychological dimension in their characterization of learning environments and they suggest that changes in thought about the character and form of learning environments trace a path in concert with the evolution and focus of psychological theory (Hannafin & Land).

Early learning environments reflect behaviorist thinking of the time and follow fundamental stimulus-response-reinforcement models. Strategies such as directed drill and practice are practical expressions of such behaviorist principles (Hannafin & Land, 1997).

A shift in focus to internal processes characterizes the emergence of cognitive psychology, and Hannafin and Land (1997) suggest that information processing theory exemplifies this shift through its examination of the selection, encoding, and retrieval of knowledge. Notions about the impact on learning of short-term memory capacity, processing depth, elaboration, meaningfulness, and schemata emerge as reflections of the exploration of learning as a collection of internally mediated processes (Hannafin & Land).

The recognition that learning and understanding are dependent on context to derive meaning drives the social cognitivist perspective to the degree that Hannafin and Land (1997) suggest, namely, that knowledge in the absence of social context is essentially inert. They further suggest that the extension of this position, that a contextually rich and authentic experience is critical to the construction of meaningful knowledge, is the foundation of constructivism (Hannafin & Land).

The essential premise of constructivist learning theory, according to Hannafin and Land (1997), is that understanding is derived through experience that serves as the catalyst for the construction of meaning. Hannafin and Land suggest learning systems must "reflect, and be consistent with, the underlying psychological model upon which they are based" (p. 174). Hannafin and Land propose that student-centered learning environments must, therefore, place great weight on three concepts:

1. Learners are constructors of their own knowledge.
2. Context is critical to understanding.
3. Experience is essential to learning.

Hannafin and Land (1997) cluster the activities, methods, and structures of learning environments into the pedagogical dimension of their characterization of grounded instructional design. They suggest that an underlying psychological model must find expression through methods, strategies, and content organization consistent with that model. Hannafin and Land further suggest that different underlying psychological models result in different methods and strategies. Thus, objectivist viewpoints incorporate hierarchical approaches to knowledge organization and strategies that focus on objective/assessment/remediation models while constructivist viewpoints focus on exploration and concrete manipulation (Hannafin & Land).

The technology-enhanced, student-centered learning environment championed by Hannafin and Land (1997) engages the learner in manipulating and investigating problems that require the learner to reason before identifying and selecting methods to explore solutions. The learner seeks out ideas, experiments to verify hypotheses, and interprets the results to derive knowledge (Hannafin & Land). Hannafin and Land emphasize that a learner in such an environment is never restricted purely to constructivist approaches and may seek out resources such as generative strategies (e.g., recall, integration, organization, and elaboration). The emphasis is on synthesizing research and theory to establish “contexts, resources, and tools to promote learning” (Hannafin & Land, p. 175).

The technology dimension of Hannafin and Land’s (1997) technology-enhanced, student-centered learning environment addresses the influence that the technological tool kit available to the learner and to the designer has on the design of learning systems. A learning system’s technology component drives the types of possible learner-system transactions, but design decisions regulate the range and character of their implementation (Hannafin & Land).

Hannafin and Land (1997) suggest that technology (a) facilitates the understanding of abstract concepts through concrete experiences, (b) facilitates selection and experimentation through the manipulation of objects, and (c) provides for the personalization of instruction with advice or appropriately timed and guided access to information. The potential to exercise new strategies or designs is a feature of technology that Hannafin and Land suggest stimulates new research and new theoretical perspectives.

Prevailing beliefs, cultural values, and individual societal roles lie at the heart of Hannafin and Land's (1997) cultural dimension for technology-enhanced, student-centered learning environments. They suggest that a culture's desire to increase, decrease, or shift educational focus follows the progression of changes in its attitudes, beliefs, and social mores. This linkage exists at every level of organization in learning systems, according to Hannafin and Land, and reflects the philosophical shifts regarding the nature of teaching, learning and technology experienced by the stakeholders in those systems.

The pragmatic dimension of grounded instructional design and technology-enhanced, student-centered learning environments reflects what Hannafin and Land (1997) identify as unique situational constraints that bridge the gap between theory and reality. While pragmatic concerns are often associated with technical constraints, Hannafin and Land note that learning requirements may force a blend of contrasting pedagogical approaches for instructional expediency.

A realistic estimation of human and technological assets and a comprehensive appraisal of situational factors are important for an effective learning system design (Hannafin & Land, 1997). An issue in the pragmatic assessment of learning system design requirements is the common confusion of a narrow perspective on the performance requirements for realistic estimation of capabilities (Hannafin and Land). Hannafin and Land propose that such confusion must be overcome in order for learning system design to evolve in response to advances in technological, psychological, and pedagogical research.

The Interdependence of the Five Dimensions

The five dimensions or foundations for grounded instructional design and technology-enhanced, student-centered learning environments (psychological, pedagogical, technological, cultural, and pragmatic) must function as an integrated whole in order for the systems built upon them to be effective (Hannafin & Land, 1997). The greater the interdependencies of the dimensions in a system, the greater the likelihood of success in the setting for which the system is designed (Hannafin & Land). Hannafin and Land provide a set of assumptions for assessing degree of alignment of a learning system's foundations:

1. Instruction, traditionally operationalized, is too narrow to support varied learning environments.
2. Understanding is best supported when cognitive processes are augmented, not supplanted, by technology.

3. Learning environments need to support underlying cognitive processes, not solely the products of understanding.
4. Understanding evolves continuously.
5. Individuals must assume greater responsibility for their learning.
6. Learners make, or can be guided to make, effective choices.
7. Learners perform best when varied or multiple representations are supported.
8. Knowledge is most meaningful when rooted n relevant scaffolded contexts.
9. Understanding is most relevant when rooted in personal experience.
10. Reality is constructed via interpretation and negotiation.
11. Understanding requires time.

Hannafin and Land’s (1997) grounded instructional design approach provides a comprehensive framework through which one may look outward to characterize and evaluate the properties of a learning system. It also provides a framework for reflectively looking inward at the theoretical roots and conceptual lineage constituting the evaluator’s perspective.

Northrup and Rasmussen (2001) apply the grounded design model as a context for addressing design decisions to facilitate learning outcomes in an online graduate university degree program. The five dimensions of grounded design are addressed with specific, practical prescriptions for implementation in the program (Northrup & Rasmussen).

The psychological dimension of the program reflects situated cognition theory as the developers have implemented course pair sequences clustered around common realistic contexts (Northrup & Rasmussen, 2001). Included in each pair of courses was a unique real world application problem based on the learning objectives associated with the course pair (Northrup & Rasmussen).

The pedagogical dimension of the program is expressed in experiences anchored in authentic activities that allow learners to transfer knowledge and problem-solving strategies to their own professional work environments. The design features of the program include (a) a mentor for heuristic and technical support; (b) course pairs situated in common learning experiences; (c) cognitive apprenticeship through scaffolding, as well as both expert and peer coaching; and (d) collaborative learning communities (Northrup & Rasmussen, 2001).

The technical dimension includes a range of support and tools that foster a dynamic communications network (Northrup & Rasmussen, 2001). A critical feature of the technical support of the program is that the integration of the technology is driven by the instructional demands, and is responsive to the evolution of those demands, instead of the instructional model being driven by the technological capabilities at the program's disposal (Northrup & Rasmussen).

The learning community of the program's participants shapes the cultural dimension of Northrup and Rasmussen's (2001) degree program. Public and private sector internships, the collaborative nature of the learning activities, coaching, and mentoring reflect the work situations and interests of the learners . The program's learners are typically midcareer professionals focused on the application of new knowledge and strategies (Northrup & Rasmussen).

Pragmatic concerns drive decisions regarding administrative support, student support services, and technological capabilities. Technology issues that affect the pragmatic implementation of the program include (a) security, (b) personal and administrative data, (c) connectivity, (d) troubleshooting, and (e) maintenance (Northrup & Rasmussen, 2001).

The Psychological Dimension

The psychological dimension of grounded learning systems design addresses fundamental concepts regarding knowledge and the nature of knowing. These concepts, when framed in the context of learning object-based tool development, fall into four areas of focus: (a) the acquisition of information, (b) knowledge representation, (c) knowledge organization in individuals, and (d) the role of social context in the acquisition and usability of knowledge. The psychological dimension of a grounded learning object-based instructional design tool can build on the recognition that although there may be a common process for acquiring information from the senses and storing that information, the methods for representing that information, organizing it, and acting upon it may vary widely among individuals. The variance depends on their individual cognitive processing preferences, the schema in an activated state at a given time, the robustness of the organizational state of their cognitive structure, and both the depth and range of their experiences.

The Acquisition of Information

Atkinson and Shiffrin (1968) approach the topic of cognitive structure from a systems and process perspective. They divide the memory system into two categories of components: (a) permanent structural features and (b) control processes (Atkinson &

Shiffrin). Permanent features include the physical structures representing the basic memory stores and built-in processes, particularly for sensory stimuli. Control processes are individually constructed cognitive features that are activated in response to specific situations. The control processes that an individual selects determine the nature and degree to which new information and cognitive structure interact. Examples of control processes provided by Atkinson and Shiffrin include coding procedures, rehearsal operations, and search strategies. Atkinson and Shiffrin identify three variables that affect the activation of control processes: (a) the context within which the information is received, (b) the meaningfulness of the information, and (c) the individual's experience and history.

The model Atkinson and Shiffrin (1968) use for describing the structural components of memory includes three interactive features: (a) the sensory register, (b) short-term store, and (c) long-term store. Information flows through these features of memory structure in a sequence that Atkinson and Shiffrin describe as a four-step process. First, the individual scans the sensory registers. A search of long-term store memory is then made to identify matches or relevant features meriting closer attention. Information that is selected for closer examination is moved into short-term store memory where control processes act upon it. The control processes either allow the information in short-term store memory to decay and so exit the cognitive system, or fix the information into long-term store memory with varying degrees of permanence or utility (Atkinson & Shiffrin).

The transfer of information from short-term store memory to long-term store memory is driven, both in degree and efficiency, by the nature of the control processes in a state of activation at the time the information is in short-term memory store (Atkinson & Shiffrin, 1968). The robustness of information transfer from short-term store memory to long-term store memory is greatest when overt responses from the individual are required during the process. This proposition lends weight to interactivity as a powerful instructional tool (Atkinson & Shiffrin).

Long-term store memory provides the foundation for cognitive structure (Atkinson & Shiffrin, 1968). It is the place where information is fixed into a sort of knowledge matrix, the permanence of which varies with factors such as decay, interference, or loss of strength (Atkinson & Shiffrin). Ausubel (1968), Jonassen and Henning (1999), and others propose that these factors are expressions of the relative position of the information in the cognitive structure, its frequency of access, and the robustness of its connections to surrounding propositions.

Atkinson and Shiffrin (1968) suggest that the organization of information while it is in short-term store memory aids the efficiency of search processes. They further suggest that it speeds the recall of that information through the long-term organizational structure.

Coding is the process of converting information from the sensory registers and short-term store memory into a form that can be manipulated by processes which facilitate the transfer of information in short-term store memory to long-term store (Atkinson & Shiffrin, 1968). Atkinson and Shiffrin identify two common strategies for encoding information into long-term store memory. The first strategy involves the incorporation of the new information into natural language structures. The second strategy facilitates the association of new information into long-term store memory through the use of visual imagery (Atkinson & Shiffrin).

Knowledge Representation

Exemplars. The exemplar view of concept representation suggested by Bareiss (1989) is based on the proposition that the definition of a concept is implicit in its instances. No abstract definition exists, which makes important conceptual extensions such as feature correlation, feature value assignment, and concept instance recognition both less ambiguous and more efficient (Bareiss). The critical feature of Bareiss' model is that concepts are learned by individuals through the collection and storage of examples of its category members. He suggests that the individual employs two storage strategies in collecting concept instances. One such strategy is to store every example that is unique (compared with existing instances) when it is evaluated for feature correlations and feature values (Bareiss). The other strategy involves evaluating and storing a collection of the best examples based on their resemblance to a set of criteria extracted from common features and feature values of existing instances. The number of examples stored depends on the individual's requirement for precision in the application of the concept; more examples may provide a more extensive set of features whose values appear to be defined with greater resolution (Bareiss).

Concept classification in Bareiss' (1989) exemplar model is a two-step process. An individual classifies an object when it is first encountered based on its similarity to any existing exemplar. The individual then makes a more intensive examination of the object to look for a high degree of matching among several exemplars (Bareiss).

Bareiss (1989) identifies two problems with the exemplar model. Not every collection of exemplars necessarily represents a reasonable concept, and the commonality of exemplars is usually not explicit among interacting individuals. These problems suggest that the exemplar model may have a greater value describing cognitive processing for an individual, but a lesser value as an explanatory tool for communication (Bareiss).

Generic tasks. Chandrasekaran (1989) applies a model similar to the exemplar model for knowledge representation proposed by Bareiss (1989) to collections of knowledge-based reasoning tasks. He suggests that knowledge-based reasoning is an expression of combinations of generic reasoning building blocks. Each reasoning task, or strategy, posesses three elements: (a) the kinds of information required as an input and the resulting output information, (b) a way to present and organize knowledge required to perform the task, and (c) the process (e.g., algorithm, control, problem solving) that the task employs (Chandrasekaran).

Various combinations from among five generic tasks account for most knowledge-based reasoning operations according to Chandrasekaran (1989). The five are (a) hierarchical classification, (b) plan selection and refinement, (c) knowledge-directed information passing, (d) hypothesis matching, and (e) hypothesis assembly (Chandrasekaran).

The first two generic tasks involve the use of preexisting mental structures and the placement of information within them. Hierarchical classification involves identifying the categories of information that apply to a given situation (Chandrasekaran, 1989). Plan selection and refinement trace the path of likely strategies through a hierarchy of plans and strategies used to define an object (Chandrasekaran).

Knowledge-directed information passing is the task of determining the attribute of a unit of information, or datum, based on conceptually related data (Chandrasekaran, 1989). This type of task may be used for classification or design and often makes use of a database. The task uses domain knowledge to transform database contents into a form required for a particular task (Chandrasekaran).

The last two generic tasks involve the application of hypotheses to process information. Hypothesis matching attempts to find a good fit between a hypothesis and a given situation represented by hierarchical evidence abstractions (Chandrasekaran, 1989). Hypothesis assembly defines the construction of composite hypotheses to account for a set of data while meeting the criteria of completeness and economy (Chandrasekaran).

Schema. West et al. (1991) build on Bareiss' (1989) exemplar model for knowledge representation and Chandrasekaran's (1989) generic tasks by embracing the notion of schema theory. They identify schema as information patterns, structures, and scaffolds of two basic types. They describe the first schema type as packets or bundles of data, which are characterized as either data itself or information about the state of data. They draw on the work of Rumelhart and Ortony (1977) to describe a second class of schema that represents processes that are defined as procedures for handling or organizing data.

The notion of schema activation is important because of its implications for effective learning. West et al. (1991) suggest that at any given moment, an individual has a certain mind set, literally a limited set of schema, in consciousness. These schemas govern what stimuli the individual perceives, and the initial interaction between new stimuli and the active schema determine what new schema are invoked, if necessary, to process and integrate the new information. The patterns of internal representation determine cognition, and the more complex the event or experience, the greater the influence of the schema in its integration (West et al.). West et al. assert that the effects of poor matches between schema and events may be so profound as actually to preclude the activation of schema that may be the best fit for the new information. Furthermore, other constructs, such as affect and belief, may introduce resistance to change (West et al.).

West et al. (1991) explore four important concepts described as modes of learning by Piaget (1952) to explain the dynamic interaction between schema and new information in the learning process: (a) accommodation, (b) assimilation, (c) accretion, and (d) restructuring. Accommodation involves the mind conforming to the environment so that entirely new schemas are formed in response to external conditions. Assimilation is essentially the incorporation of new information into the current structure of existing schema. Accretion involves the addition of details, a sort of tuning modification of existing schema. Routine facts that enhance the discriminating power of the schema are processed in this way. Finally, restructuring represents the radical rearrangement of existing schema in response to new information that calls existing structural logic into question (West et al.).

Types of Knowledge

West et al. (1991) propose that knowledge with different properties is processed and organized differently in cognitive structure. They support three broad categories or types of knowledge: (a) declarative, (b) procedural, and (c) conditional (West et al.).

Declarative knowledge is described by West et al. (1991) as factual in nature. It is stored in the form of propositions and networks of propositions. Propositional networks are subdivided into two types: (a) semantic and (b) episodic. Semantic networks represent lists of elements that may or may not have strong relationships among each other, but whose access and recall is aided by their relative position in the network. They also support Anderson's (1985) notions on episodic networks by suggesting that they represent connected chains of proposition whose relationships with each other are usually in the form of historical narrative. Procedural knowledge consists of order-specific, time-dependent, sequential instructions that characterize knowing how to accomplish some task (West et al.). The distinction between procedural knowledge and episodic network declarative knowledge is the focus on the process independent of content in the former and the focus on the relationships among a sequence of specific facts in the latter (West et al.).

Prawat (1989) suggests that conditional knowledge represents a higher order cognitive process in that it is concerned with the description of specific criterion combinations and contexts that may be matched to a range of responses to them. West et al. (1991) draw on this to conclude that conditional knowledge defines the knowing when and why to use a procedure.

Once taxonomy of knowledge is described, the organization of knowledge in cognitive structure becomes a concern for the learning theorist (West et al., 1991). West et al. propose that the value in well-structured knowledge lies in its logical order, its usefulness in making predictions about the future, and its value for making inferences when there are gaps in its structure.

Mental Models

Jonassen and Henning (1999) advance the notion of schema theory to incorporate natural tasks and situations as the foundations of mental models representing knowledge. Jonassen and Henning provide a definition of mental models that emphasizes structure and relationships as critical features: “Mental models are representations of objects or events in systems and the structural relationships between those objects and events” (p. 37).

Jonassen and Henning (1999) propose that learners model new knowledge through the adoption of allegory or metaphor to aid in structure mapping. They also suggest that structure mapping is an effective concept in understanding cognitive structure as long as five assumptions are taken into account:

1. Mental models are internal representations.
2. Mental models are linguistically mediated.
3. Mental models are networks of concepts. Propositions in the cognitive structure are grouped together, as Ausubel (1968) suggests, around anchoring notions that in turn are formed together into substructures which assume a place in successively more inclusive and complex groupings.

4. Concept meaning is embedded in relationships to other concepts. Jonassen and Henning suggest that the structural position of a concept with reference to others is another significant and critical dimension of its meaning that plays an integral role in the encoding and recall processes.
5. Social meaning is the intersection of individual models. Variations in experience, prior knowledge, beliefs, and abilities account for individual differences in cognitive structure, but the common elements in congruence among a number of individuals assume a significance that is important to successful social discourse. Additionally, the collective awareness of knowledge that is held in common among individuals in a group itself affects the internal structural properties of the representation of that knowledge. (Jonassen & Henning, 1999)

Another critical feature affecting the efficacy of mental models according to Jonassen and Henning (1999) is the degree to which the models can be run. They suggest that learners with poor mental models are unable to run them when they are required and perform poorly in problem-solving tasks that rely on the models as the result (Jonassen & Henning). In order to run mental models, they must be dynamic, multimodal, and multidimensional (Jonassen & Henning).

Jonassen and Henning (1999) describe the dynamic properties of mental models using analogous explanations such as the shifting of focus, activating the model, or setting attention to describe transitions of state that the learner's mental model undergoes in response to the requirements of the moment. Modes of operation or awareness also play a role in the runnability of a particular mental model. Different contexts or states of activation at the moment new information is introduced may affect what portion of the learner's cognitive structure processes it (Jonassen & Henning, 1999).

The same element of information may play an important role in a number of interconnected submodels in the learner's cognitive structure (Jonassen & Henning, 1999). The more roles the same information plays, Jonaasen and Henning suggest, the more likely it is to become a stable point in the learner's cognitive structure. However, some substructures will be better rehearsed and more stable than others. The runnability of a new model may depend on the direction the cognitive process takes at critical intersections between new knowledge and existing structures (Jonassen & Henning).

Jonassen and Henning (1999) conclude that differences in knowledge structure, visualization capability, and the generation of metaphors account for significant differences in problem-solving abilities among individuals. Furthermore, they conclude that mental models with more linear structures, lower dimensionality, and less robust metaphors negatively affect the individual's problem-solving ability in a given knowledge domain (Jonassen & Henning).

The Combination of Knowledge Organization and Heuristics

Merrill (2000) suggests that in order for an individual to solve a problem or learn, both a schema for the mental representation and organization of knowledge in the learner’s mind and heuristics for manipulating components of that knowledge must be available to the learner. Merrill identifies two large groups of problems associated with establishing appropriate mental models and heuristics in the design of instruction using learning objects: (a) categorization and (b) interpretation.

Categorization. Categorization problems are further divided by Merrill (2000) into either classification or generalization groups. Classification problems involve the process a learner undergoes when presented with a series of different case examples typifying distinct subclasses of a superordinate class of a particular concept. The learner must recognize the properties and values distinguishing each category. The learner must also be able to recognize those particular properties and values when encountering a new example and assign the example to the correct category (Merrill). Generalization problems require that the learner must synthesize common properties and values from a number of different class examples into a new, previously unrecognized superordinate conceptual class (Merrill).

Interpretation. The other large problem group identified by Merrill (2000) is that of interpretation, also subdivided into three smaller classes of problems: (a) explanation, (b) prediction, and (c) troubleshooting. Explanation requires that the learner apply a vocabulary of knowledge components including property, value, portrayal, condition, and consequence to characterize a mental model of a concept (Merrill). Predictions involve first the identification of the conditions that are relevant to the consequence of the prediction (Merrill). This involves recognizing the involved property set and registering their current values. The learner must also recognize the principle involved, usually expressed in an *if <condition(s)>then<consequence>* statement, and then anticipate the changes in values of the members of the property set (Merrill). Troubleshooting is essentially a sequencing problem for applying predictive conditional sets (Merrill).

Knowledge Organization and Individual Differences

Piaget (1952) proposes that “Learning involves the reciprocal assimilation of existing schemata as new objects are subsumed by them” (p. 236). Ausubel (1968) defines subsumption as the "process of linking new information to pre-existing segments of cognitive structure" (p. 58). Ausubel proposes that such modification of cognitive structure assumes a critical role in learning efficiency because

1. Associated knowledge at the point of modification of cognitive structure can have direct and specific relevance for subsequent learning tasks.
2. The structure possesses enough explanatory power to render otherwise arbitrary factual detail potentially meaningful.
3. Existing structures provide stability for anchoring newly learned details and meanings.
4. New facts are organized around a common theme that integrates them both with themselves and with existing knowledge.

Ausubel (1968) classifies new knowledge into two broad types of propositions: (a) derivative and (b) correlative. The distinction between the two types is based upon the effect they have on existing cognitive structure in the learner (Ausubel). Propositions are defined as derivative knowledge when new meaning to existing knowledge is implied through a distinct example. Such a proposition increases the density of information clustered around a specific point in the cognitive structure (Ausubel).

Correlative knowledge extends, elaborates, modifies, or qualifies existing knowledge structure because it is neither present nor implied in existing propositions (Ausubel, 1968). Cognitive structure expands in some direction as the result of the incorporation of such knowledge.

Knowledge Relationships in Cognitive Structure

Ausubel (1968) describes the relationships in cognitive structure among propositions implied by his definitions of derivative and correlative knowledge through the use of the terms superordinate and combinatorial. A new proposition may assume a superordinate position under which several existing propositions may be subsumed or attached in conceptually subordinate positions. Likewise, new propositions may be subsumed under a preexisting superordinate concept. Propositions are combinatorial when they assume a nonspecific relationship to existing ideas that share a general relevance but have no sharply defined superordinate proposition (Ausubel).

Ausubel (1968) summarizes the practical differences between propositions superordinally and combinatorially related as the former representing problem-solving knowledge and the latter being problem-setting knowledge. Superordinally configured knowledge is useful as problem-solving knowledge in that clearly defined structure provides the foundation for an efficient search path strategy. Combinatorially configured knowledge, meanwhile, is problem setting in that the introduction of new knowledge of this type forces a reexamination of the loose collection to find a precipitant superordinator (Ausubel). Ausubel also draws support for the role combinatorial relationships among propositions plays from the chunk sequencing research of Miller and Selfridge (1950) who establish that elements of meaningless discourse broken into a sequence of chunks can be recalled better than a continuous stream because the sequence of chunks itself provides relevant cues. Ausubel further explains that related material may be presented in a sequence such that each successive proposition is not dependent on the learner's mastery of the previous one. The learner benefits from the organization of the material itself because the organizational structure orients the learner in subsequent attempts to access the propositions from memory.

A Cognitive Structure Taxonomy

Ausubel (1968) defines assimilation as the interaction between new information and cognitive structure. He describes taxonomy of cognitive structure variables that define the parameters and character of the assimilation process in a systematic way. It is the properties of these variables that Ausubel asserts influence new learning and the retention of new information. Ausubel derives the framework for the assimilation model from the notions of lateral and vertical transfer proposed by Gagne (1965). He notes Gagne's assertion that lateral transfer of meaning is the extension of generalizable properties to information related tangentially and that the vertical transfer of meaning is the requirement that the learner master subordinate knowledge in order to assimilate related higher order information.

One of the variables Ausubel (1968) describes as critical to the fixing of new knowledge into cognitive structure is relevance. He suggests that learned propositions whose connections to existing cognitive structure are weak or tangential are less stable, thus less likely to be recalled in context and more likely to decay into inaccessibility than those with strong connections. He notes that relevance is a measure of the strength of the relationship between existing knowledge and new information, not a property of the new information itself (Ausubel). Furthermore, Ausubel asserts that new information, which may in fact be highly relevant to the learner's existing information, has little chance of gaining stability unless the learner recognizes that relevance.

Another factor that influences the relevance of new information is the stability and clarity of the appropriate superordinate proposition, or anchoring idea. Ausubel (1968) describes a type of cognitive bridge that extends from the anchoring point of general and inclusive information to new propositions, thus fixing it into the learner’s cognitive structure.

An equally important variable affecting the relevance of new material is the degree to which it can be differentiated from propositions that are already part of the learner's cognitive structure. Ausubel (1968) states that new knowledge must be "discriminable from the established ideational system" (p. 169).

Jolley (1973) capitalized on Ausubel’s (1968) notions of anchor points and subsumption to establish an early systematic organizational structure for knowledge that reduces each classification step to a binary choice in perception. The model’s aim is to bridge between cognitive structure and search, retrieval, manipulation, and analysis algorithms for computer-based expert systems (Jolley).

While Jolley’s (1973) effort at a binary knowledge classification system provides an encoding methodology suitable for knowledge base expert systems, its extension to a model for addressing cognitive structure and learning becomes problematic. The issues of accumulated exemplar sets proposed by Bareiss (1989), the role individual experience plays in the schema activation model described by West et al. (1991), and the multidimensional character of Ausubel’s (1968) anchor point clusters suggest that individual differences play too large a role in cognitive structure to remain unaddressed.

Negotiation in Cognitive System Linkages

Rescher (1979) addresses the nature of interconnecting linkages in a cognitive system by dividing linkages into two types: (a) probative and (b) justificatory. Probative, or evidential linkages, explore the ontological reason of why something is so by defining its specifications (Rescher). Justificatory, or explanatory, linkages define the epistemological reasons, or why something is believed to be true, for relationships among propositions. Rescher takes care to warn, however, that an explanation of why something should be true, taken by itself, doesn’t automatically make that thing true. He suggests that the negotiation of linkage classification reflects a human predisposition to reconciling the discrepancies between what individuals expect according to mental plans in use and what individuals encounter in reality (Rescher).

Rescher (1979) proposes that the process of inquiry requires a system that uses a mental map of the individual’s cognitive terrain, and that systematization is the prime instrument of error avoidance–a kind of cognitive quality control. He suggests that the cognitive map serves both to keep the wrong things out and to let the right things in, since if a proposition can be integrated into the cognitive system, then it must be accepted as true (Rescher). The system itself, in Rescher’s model, becomes the arbiter of knowledge.

Preferences in Patterns and Styles of Knowledge

Goldman (1986) raises important questions about the implications for cognitive processing that structural organization and systematization theories present. Goldman asks whether there may be preferred patterns and styles of knowledge construction and whether these may impose constraints on mental representation. He proposes that a nearly universal feature of all theories of mental representation, consistent with the notion of patterns and styles of knowledge construction, is the breakdown of experience into discreet parts and the construction of new parts (Goldman).

Goldman (1986) supports the proposition that individuals have preferences for patterns in the creation and segmentation of knowledge by drawing on the philosophical foundations of Gestalt theory in defining five features that characterize preferred or natural patterns of knowledge creation:

1. Proximity. Things that are perceived by an individual to be closer together tend to be associated with each other more often than things that are farther away from each other.
2. Similarity. Things that are perceived by an individual to possess characteristics that are like those of others are more closely associated with each other than with those that are different.
3. Continuity. Things that follow one another more closely in time or in logical sequence are more likely to be associated with each other by an individual than those which are separated by more time or sequence order.

4. Closure. Things that can be grouped together with a sense of completeness are more likely to be associated with each other by an individual than with groups of things that cannot.
5. Form. Groups of things that make regular shapes, express symmetry, or balance are more likely to be associated with each other by an individual than groups of things that do not.

Human Preferences for Hierarchical Knowledge Representation

Goldman (1986) extends the idea of organizational preferences and draws parallels between the features of natural language and those of hierarchical knowledge representation by suggesting that sentence structure is an expression of a hierarchy of concepts dependent on semantic memory. He also associates the notion of class inclusion arrays, or taxonomies, with visual and temporal knowledge (Goldman). Goldman asserts that the natural parts of a collection of propositions in an individual’s memory provide strong retrieval cues for the original whole to the extent that good cues are up to five times more effective in retrieving information than bad ones.

Goldman (1986) illustrates the pervasiveness of human preference for hierarchical representation through citation of Restle and Brown’s (1970) examination of the way musicians learn music. Restle and Brown found that music is an expression of hierarchical representation, and that musicians learn new music in a top down hierarchy of patterns, not as a sequential string of tones.

Goldman (1986) addresses the complexity of working from a knowledge hierarchy model by expanding the notion of hierarchy to include features supported by the proposition that the brain possesses an innate computational mechanism for constructing shapes, especially shapes in motion and in three dimensions. He uses as an example of such a feature the common preference for symmetry (Goldman). The inference Goldman draws from the evidence for human preference for symmetry is that individuals actually employ a rather narrow set of representation-forming operations and have preferences for the sequence in which those representation-forming operations are performed. This inference is consistent with the notion of generic task sets in knowledge-based reasoning as proposed by Chandrasekaran (1989).

Representation-Forming Operations

Goldman (1986) identifies three types of representation that serve as the foundation for the narrow set of representation-forming operations: (a) temporal strings, (b) spatial images, and (c) abstract propositions. Temporal strings involve the fixing of information in sequence along a time line. Spatial images place items of information in relation to each other with varying degrees of proximity. Abstract propositions involve an iterative process of placing new knowledge into relational slots and then attempting to fill in missing slots with existing information or queries for new information (Goldman).

Linguistic patterns are useful to Goldman (1986) in demonstrating evidence of the pervasiveness of analogy as a form of abstract proposition. He suggests that analogy in the form of linguistic patterns is critical to problem solving and that the abstract proposition feature of relational slot substitution is the key preferred operation in the process (Goldman).

A significant issue with hierarchies and natural preferences in concept representation is the potential for the rejection of certain propositions when their properties fall outside the range of the individual's preferences (Goldman, 1986). Goldman also suggests that the complete failure to perceive certain propositions as meaningful is another possible consequence of individual preferences in representation formation.

The role that the notion of originality plays in the development of concept representations in the individual is one that Goldman (1986) explores by suggesting that an individual usually finds some new ideas more attractive than others. Goldman suggests that the metric at work in the establishment of a notion's attractiveness as it is processed by the individual has four important features:

1. The preference ranking of processing operations is not universal for all individuals.
2. Individuals are persistent in applying existing, familiar operations.
3. Individuals apply operations in combinations to process information and tend to use familiar combinations.
4. Individuals tend to apply the same set of operations to different sets of initial ideas.

Recognition that learners have preferences in the manner in which they organize and process knowledge is important to instructional system designers. That those preferences can be persistent, yet open to modification given certain conditions, also informs designers of instructional systems of the criteria for effective system design.

Visual Imagery as the Medium for Knowledge Processing

Visual imagery representations of knowledge serve as the media upon which processes act in Kosslyn's (1981) cognitive structure model. Kosslyn divides those processes into four types. The first such process is image generation, in which new representations of information are created. The second process is image inspection, or the detailed examination of existing imagery in anticipation of using specific features for a purpose. The third process is image transformation: the alteration of an image's properties in response to new information. The fourth process is the spontaneous use of imagery to retrieve information from long-term memory.

Kosslyn (1981) describes two ways that visually coded information supports the execution of cognitive tasks. Storage of information is one way that cognitive tasks are supported through visual coding, particularly in aiding the permanence of information in long-term memory. Furthermore, the quantity of information conveyed into short-term memory for operations in imagistic form is greater than for nonimagistic information. The richness of the information reflects the interdependence of size, shape, orientation, and location of elements within the image (Kosslyn). Another way that visual coding may support cognitive tasks is the deployment of operations on knowledge representations in the visual memory buffer. An example provided by Kosslyn is that of trying to remember the number of windows in a person's living room. First, one retrieves a mental image of the person's living room from long-term memory, and then one performs the cognitive operation of counting the windows recalled from the mental image (Kosslyn).

Conversely, Kosslyn (1981) proposes that imagery may also play a role in constraining thought processes. A cognitive function may in fact be bound by the collection of symbolic information that one is able to retrieve while performing that function (Kosslyn).

Knowledge as Symbols Enabling Logical Operations

Cummins (1989) addresses the nature of meaning in mental representation by approaching the concept through four representational models. He suggests that the basis of cognition is the raw material of mental objects or ideas. He explores another dimension through the notion of imagery's facilitation of identifying and categorizing shared properties among objects. Cummins also discusses the importance of mental representations that enable computation and logical operations such as symbols. Finally, Cummins suggests that theorists often overlook the actual neurophysiological states of the brain as influences on the character of mental representation.

The operational nature of mental representation is of particular significance, according to Cummins (1989), and he characterizes four dimensions along which operations occur:

1. Similarity. The degree to which one thing is like or unlike another thing.
2. Covariance. The degree that changes in one thing cause change in another.
3. Adaptation. The estimation of covariance yet to take place between two things based on past history.
4. Function. The computational role the representation is to play.

Cummins (1989) suggests that mental representations are uniquely characterized by their contents. He concludes that the nature of the contents of a mental representation is determined by the functional role the representation is to play, which is consistent with the notions promoted by West et al. (1991) and Goldman (1986) regarding the influence of schema activation and individual cognitive processing preferences.

Davidson, Deuser, and Sternberg (1996) propose that new mental representations are constructed through three mental processes: (a) selective encoding, (b) selective combination, and (c) selective comparison. Selective encoding involves the restructuring of previously irrelevant representations into relevant ones, and vice-versa. Selective combination reorders a problem's elements in a way that was not previously obvious. The discovery of hidden relationships between new knowledge and old information represents selective comparison and is often manifested in constructs such as analogy or metaphor (Davidson et al.).

Problem Solution Planning

Davidson et al. (1996) also suggest that there are three important characteristics of problem solution planning. One such characteristic is that problem solution planning is most likely to occur in cases where the problem has new elements or is complex. In other words, solution planning often follows when preferred cognitive processing approaches as described by Goldman (1986) prove inadequate. Another characteristic is that planning is an abstract activity, not concrete, and is fluid in that its character is dependent on situational context. This notion is consistent with Chandrasekaran's (1989) ideas about generic task structure. Finally, problem solution planning follows a cost and benefit model. If the problem solver selects a lower order planning strategy for a complex problem, the intended time and effort savings driving such a poor choice are doubly lost if the solution fails and the problem solver has to begin again with a more involved strategy (Davidson et al.). Such a model is facilitated by the multidimensional anchor point cognitive structure proposed by Ausubel (1968). The implication for designers of learning systems is that the problem-solving strategies embedded in the instruction must not only prove challenging enough to trigger solution planning, but must also reflect the varied approaches and cue the learner to invest the appropriate level of effort in deriving the solution plan.

Knowledge and Social Context

One direction of thought in cognitive theory reflects the conviction that since few people ever develop in complete isolation from others, the information processing functions of the individual cannot be meaningfully examined without taking into account the effect of the person's experience. The evolution of this line of thought begins with early concepts of symbolic representation and interaction with the environment.

Vygotsky (1934/1962) addresses concept formation by suggesting that it is a cyclic and dynamic movement of thought between the particular and the general and back again. He stresses that it is not the simple interplay of associations within the cognitive structure that forms a concept, but a specific and unique combination of a diverse range of cognitive functions, taken all together (Vygotsky).

Scheffler (1965) addresses a fundamental issue regarding context by examining the epistemological function of knowledge. He divides that function into two classes: (a) the state of knowing that and (b) the state of knowing how (Scheffler).

A feature of competence, a measure of knowing how, that Scheffler (1965) identifies as important is that it must always be interpreted within context. Furthermore, Scheffler distinguishes between facility and skill in discussing competence. He proposes that facility occupies one end of a spectrum in which activity is routine, or procedural, while the other end of the spectrum is occupied by critical skills that involve an engagement of judgment in performance (Scheffler). Simple facility relies heavily on the assumption of rigidity in the context of performance, while critical skills require a thorough reexamination of situational context, building upon past experience and connections to existing knowledge to estimate the best approach to a new task (Scheffler).

Ramsey (1992) traces an evolutionary path through empiricist, rationalist, quasi-linguistic, and monadic models to arrive at structural holism as a meaningful philosophical account of propositional representation. The essence of Ramsey's discussion is that the development of one line of philosophical thought about mental representation has moved from a focus on universal, discrete, granular elements of information arranged in various combinations, through common clustered elements similar to linguistic phrases and idioms, to complete sets of representation structures unique to the individual. He suggests that it is not possible to pinpoint a single element in cognitive structure that accounts for a specific belief or behavior. The implication is that there are no discrete propositional states; rather, each person possesses a single holistic belief state, individual propositions of which are simply localized, instantial characteristics of that state. In effect, propositions are not components of belief states; simply features of them (Ramsey).

While the structural properties of representation in his holistic model play an important role in cognitive processes, Ramsey (1992) proposes that a more critical element is the degree to which a proposition is activated or “causally implicated in the structure’s internal processing” (p. 257). The invocation of different propositions may result in different states of activation of representational elements and thus produce belief states with very different structural properties (Ramsey).

Ramsey (1992) uses the tenets of structural holism to build the concept of connectionist representation. Connectionism characterizes representational networks in terms of the interaction among units. Ramsey defines these units as the prototypical properties of things, lexical concepts, and propositions arrayed in a network for learning. He classifies them into three different types: (a) input units, (b) intermediary layers of hidden units, and (c) output units (Ramsey). Ramsey describes the intermediary units as hidden because the individual is unaware of the associative processes and activation patterns at work in response to the input units and only becomes conscious of the change in state between input and output units. He proposes nonetheless that representations are determined by the activity patterns of the hidden units (Ramsey). An important feature of Ramsey’s model that is consistent with West et al.’s (1991) schema activation model and Chandrasekaran’s (1989) generic task structure ideas is the notion that a relatively small number of units may produce a very large number of activation patterns, thus producing a very large number of different representations.

Ramsey (1992) proposes that a connectionist view of learning involves the process of modifying the cognitive system so that hidden unit activation patterns formed from unusable initial inputs are replaced with functionally useful states as the individual’s network of representational experiences organizes them into portioned classes or groups. The line of thinking that illustrates the interconnectedness of knowledge and the importance of those connections to learning has significance for developers of an instructional design tool based on collections of knowledge objects. Schank and Abelson (1995) carry this line of thinking to a logical terminus by assigning critical importance to the framing of knowledge into coherent stories.

Knowledge as Stories

Schank and Abelson (1995) propose that the social functions of knowledge are grounded in stories and the cognitive skills required to understand, remember, and tell stories. They address the issue of other kinds of knowledge that do not seem to fit into this model, such as facts, beliefs, lexicons, rule systems, and grammar by suggesting that they are most often used to index stories, noting that “people do not hold conversations in these domains” (p. 80).

Schank and Abelson (1995) also suggest that as people become more expert in a domain, they become more *storified*, a term they borrow from narrative psychology. They propose that information is stored as coherent stories or as general scene memories. Telling the story of a new experience soon after the experience fixes it into memory as coherent information, and stories told in many different ways become more robustly indexed, thus more powerful as a retrieval tool (Schank & Abelson).

Schank and Abelson (1995) address comprehension of new information by suggesting that it is a process whereby one of three things occurs. One may find a story of one’s own that is similar to the newly experienced events and incorporate features from the new experience. One may construct a story from scenes that are less relevant in older, existing stories and new information from the current experience. Finally, one may create an entirely new story from salient elements of the new experience (Schank & Abelson).

Problem Space Representation as a Solution Limitation

Petraglia (1998) proposes an information processing paradigm that consists of a three-way correspondence among objects in the external world, the language used to encode these objects symbolically, and subsequent representations of these objects in the brain. He describes knowledge representation as the mechanism for making sense of the flood of information coming from the senses (Petraglia).

Petraglia (1998) further proposes, like West et al. (1991), Goldman (1986), and Chandrasekaran (1989), that one's representation of the problem space itself determines the possible courses of action a person may take to resolve a problem. Problems may be, according to Petraglia, either well structured or ill structured. Well-structured problems lend themselves well to algorithmic solutions with finite parameters. Additionally, Petraglia requires well-structured problems to have testable resolutions with unambiguous solutions. Ill-structured problems, on the other hand, emerge from task environments permeated by contingency (Petraglia). Solutions for ill-structured problems are equivocal and vary in acceptability with the circumstances. Context and contingency drive best case resolutions (Petraglia). Furthermore, ill-structured problems are difficult to classify; thus problems that appear to have similar characteristics may be fundamentally different (Petraglia).

Petraglia (1998) proposes that the collection of difficulties associated with ill-structured problems is the fundamental flaw in the computational model of information processing and its theoretical extension, cognitivism. He proposes that cognitivism fails to account for everyday contexts and the social character of human cognition. Petraglia draws on what he terms the sociohistorical school of psychology, based on the work of Vygotsky (1934/1962) and his associates, to establish three assumptions about cognition that must be considered in the development of technology-based tools for learning. First, he proposes that a developmental approach to cognition is required. Secondly, Pretraglia stresses that mental functioning is derived from social interaction. Finally, he suggests that social practices are dependent on both the physical and mental tools used to engage them (Petraglia).

Petraglia (1998) derives his notions about situated cognition from Vygotsky's (1934/1962) proposition that knowledge is situated in culture and historical context. He traces this idea through the position that the situation shapes both the knower and the knowledge to conclude that thinking is not an abstract manipulation of symbols, but a "process embedded in our physical interactions with the world" (p. 52).

Distributed Intelligence

Another dimension of Petraglia's (1998) discussion of the dynamic, socially interactive nature of cognition is the concept of distributed intelligence. The individual serves as a node in this model within the ecology of a larger cognitive network. Petraglia suggests that tools and other beings extend the range of our cognition and in some cases allow us to bypass normal cognitive processes as in the examples of unconscious awareness of spatial relationships and object significance.

The outcome of Petraglia's (1998) discourse on the sociocultural underpinnings of cognition and his general dissatisfaction with other transmission models is his advocation of a constructivist metatheory based on authenticism. He summarizes his position this way: "Knowledge is constructed from prior knowledge and experience derived from participation in activities distributed across social, cultural, and material dimensions" (p. 55).

Petraglia (1998) proposes that tasks and solutions are always equivocal in the real world and that there are always multiple pathways through the problem space. Cognitive flexibility is a requirement because no single perspective is adequate for representing ill-structured problems. Furthermore, problems are often revisited over time from within rearranged contexts (Petraglia).

Cobb and Bowers (1999) examine the underlying assumptions of situated and cognitive perspectives in terms of the individual in the world, much as material objects are situated in relation to each other in physical space. They propose, however, contrary to the cognitivist assumption, that not all skills require a social context in order to be learned and that individual actions are elements of a social system and are part of that system even when the individual is physically removed from others in the system (Cobb & Bowers).

Cobb and Bowers (1999) suggest that "learning is synonymous with changes in ways that an individual participates in social practices" (p. 6). They extend this line of thought to suggest that knowledge is embodied in activities such as perceiving, reasoning, and talking (Cobb & Bowers). They conclude that the portability of reasoning skills and knowledge is necessarily dependent on the degree of fidelity of the new context to the one in which learning originally takes place. They use this intimate relationship between activity and learning to propose that researchers focus less attention on the relationship between theory and instructional design prescriptions and more attention on the relationship between theory and practice (Cobb & Bowers).

Jonassen and Henning (1999) also address the proposition that situated social practice shapes cognition and thinking. Their position is that “Knowledge is embedded in the activities and processes that people engage in and the discourse used to make meaning of the activities” (p. 40). They go further to suggest that objects in the world assume a role in cognitive structure. “Knowledge is embedded in physical artifacts that are the objects of activity” (p. 40). These three elements–activities, processes, and objects–play a fundamental role in the development of mental models because they possess the capacity to fix meaning into cognitive structure (Jonassen & Henning).

Knowledge Embedded in Social Context

Knowledge developed in the social context is classified by Jonassen and Henning (1999) into four different types: (a) activity-based knowledge, (b) social and relational knowledge, (c) conversational and discursive knowledge, and (d) artifactual knowledge. These four knowledge types are essentially an evolution of their earlier notions into a more comprehensive social setting. Activity-based knowledge is an extension of the concept of structural knowledge as it is expressed externally through behavior (Jonassen & Henning). Social and relational knowledge reflects the manifestation of performance and procedural knowledge through the interactions among individuals engaged in collaborative work (Jonassen & Henning). Reflective procedural knowledge lies at the heart of conversational and discursive knowledge in that it involves the communication of internalized information to others, the manner and style of which shape its character and effectiveness (Jonassen & Henning). Finally, the notion that objects themselves possess meaning assumes a more formal state in Jonassen and Henning's concept of artifactual knowledge–the idea that objects can become powerful collective symbols.

Jonassen and Henning (1999) suggest that the combination of influences from this collection of knowledge in the social context is in fact a socially negotiated community mental model. This community mental model serves the purpose of aiding members of a community of practice to function individually through access to the collective knowledge of other members (Jonassen & Henning).

The Pedagogical Dimension

The pedagogical foundation of a grounded learning object-based instructional design tool includes three areas of focus. First, an examination of the orientation of the pedagogical approach addresses the theoretical foundation characterizing the instructional process. The role of learning objects in the instructional process is next addressed by examining the relationship between the benefits and limitations of learning object technologies and instructional design and delivery. Finally, instructional strategies that are consistent with both the pedagogical orientation and learning object technology are addressed.

Constructivist Orientation

Lebow (1993) suggests that much of the debate about the efficacy of constructivism is the result of confusing constructivism for a method, not a philosophy, and also of confusing instructional systems design for a philosophy when it is, in fact, a method. He identifies the traditional educational technology values as replicability, reliability, communication, and control, while listing the seven primary constuctivist values as collaboration, personal autonomy, generativity, reflectivity, active engagement, personal relevance, and pluralism (Lebow).

Lebow (1993) attempts to reconcile these two value sets where conflict occurs by proposing five principles for constructivist instructional systems design:

1. Maintain a buffer between the learner and the potentially damaging effects of instructional practices. The thrust of this principle is that failure to influence positively the learner’s feelings about the material to be learned and the learning experience dooms the effectiveness of the instruction. Four subprinciples provide more specific approaches for instructional designers: (a) increase emphasis on the affective domain of learning; (b) make instruction personally relevant to the learner; (c) help learners develop skills, attitudes, and beliefs that support self-regulation of the learning process; and (d) balance the tendency to control the learning situation with a desire to promote personal autonomy.
2. Provide a context for learning that supports both autonomy and relatedness. Cooperative group learning and collaborative problem solving reinforce

personal responsibility and individual accountability while promoting knowledge construction as a communal enterprise.

3. Embed the reasons for learning into the learning activity itself. Lebow suggests that when learners find what is presented in the instructional environment is inconsistent with the experiences that form their world view, the knowledge fails to transfer to other settings where it would be applicable. Cognitive apprenticeships, project-based learning, and experiential learning provide the authenticity that facilitates knowledge transfer to other, related situations.
4. Support self-regulation through the promotion of skills and attitudes that enable the learner to assume increasing responsibility for the developmental restructuring process. Lebow suggests that feelings, intuitions, attitudes, values, interests, significant relationships, and learner commitment are inseparable elements of the learning process. If learners are afforded the opportunity to exercise control over these elements within the context of learning environments, then constructivist instructional practices aid the learners in restructuring their own cognitive development.
5. Strengthen the learner's tendency to engage in intentional learning processes, especially by encouraging the strategic exploration of errors. The purposeful processing of information in active pursuit of a desired learning goal depends on three factors: (a) the learner's conception of knowledge, (b) what level of ability the learner believes the learner possesses, and (c) the influence of the learning situation. If the learner's conception of knowledge and learning are

> impoverished, his ability to manage his learning behavior suffers and his own assessment of his abilities is inaccurate. One constructivist solution to this problem is rooted in the proposition that the type of goal a learner pursues shapes the learner's response to the learning situation. Furthermore, the learner's appraisal of past successes and failures cumulatively become a regulating force in the kinds of learning situations chosen in the future. A constructivist learning environment must use error as a positive force for creating a kind of disequilibrium that enables self-reflection and conceptual restructuring. Error provides opportunity to modify mental models and to establish alternate frames of reference, thus refining the self-questioning processes, goal setting, and engagement in authentic learning situations.

Petraglia (1998) identifies three mediating theories that serve as bridges between constructivism and its pedagogical application: (a) collaborative learning, (b) apprenticeship and legitimate peripheral participation, and (c) cognitive flexibility. Learning and thinking in collaborative learning environments is a thoroughly social experience. It is inhabited with mentors, experts, and advanced peers who participate in the extension of the learner's range and depth of knowledge through interaction (Petraglia).

The notions of apprenticeship and legitimate peripheral participation are grounded on the propositions that knowledge is rooted in personal experience and that real tasks increase learner motivation. Petraglia (1998) promotes the term *cognitive apprenticeship* to represent the replication of the critical elements of an actual apprenticeship in the classroom through the aid of technology. He describes legitimate peripheral participation as the activity of observers of more expert, fully engaged participants.

Knowledge Objects as Instructional Design Components

Merrill and the ID2 Research Team (1996) describe an overarching theory, which they call instructional transaction theory, that they believe addresses the requirements of scientifically validated, computer-driven instructional design and learning more completely than traditional instructional systems design (ISD) and instructional design theory. Merrill and the ID2 Research Team propose that an instructional transaction theory-based instructional design expert system must execute six functions:

1. Select knowledge objects for instruction.
2. Sequence those knowledge objects.
3. Select transactions appropriate for teaching a selected knowledge object.
4. Sequence the transactions.
5. Enact transactions through interaction with the learner.
6. Adapt the enactment of the transaction to meet the needs of specific individuals.

Merrill and the ID2 Research Team (1996) identify three distinct elements comprising instructional transaction theory: (a) descriptive theory of knowledge, (b) descriptive theory of strategy, and (c) prescriptive theory of instructional design.

The descriptive theory of knowledge addresses the concept of knowledge objects and knowledge interrelationships. Merrill and the ID2 Research Team (1996) identify three types of knowledge objects: (a) entities, (b) activities, and (c) processes. Knowledge interrelationships include (a) components, (b) properties, (c) abstractions, and (d) associations between entities, activities, and processes.

Merrill and the ID2 Research Team's (1996) descriptive theory of strategy addresses transaction shells and conditional parameters. They describe transaction shells as a set of rules or algorithms for selecting and sequencing knowledge objects as well as for passing messages to knowledge objects to control their behavior and interactions with other objects (Merrill & ID2 Research Team). Merrill and the ID2 Research Team identify five groups of transaction shells: (a) component, (b) abstraction, (c) association, (d) sequence, and (e) enact.

The component group of transactions enables the learner to acquire knowledge about particular learning objects that is prerequisite to all other transactions. It consists of (a) identification, (b) execution, and (c) interpretation (Merrill & ID2 Research Team, 1996).

Abstraction transactions offer learners the ability to identify class, subclass, and instance relationships among knowledge objects and thus generalize knowledge by developing an abstraction model of the general case of an entity, activity, or process (Merrill & ID2 Research Team, 1996). Classes of abstraction transactions include (a) judge, (b) classify, (c) generalize, and (d) transfer (Merrill & ID2 Research Team).

Association transactions provide the learner knowledge about significant relationships among knowledge objects (Merrill & ID2 Research Team, 1996). Association transactions include

1. Decide. Such transaction enables the learner to select among alternative entities, activities, or processes.

2. Use a tool. The learner uses one activity to do another activity.
3. Use an analogy. The learner uses a model process, entity, or activity to learn a new one.
4. Substitute. The learner modifies a process, entity, or activity to create a new one.
5. Design. The learner is enabled to invent a new entity or activity.
6. Discover. The leaner is enabled to discover a new process.

Sequence transactions are driven by learner characteristics such as motivation and experience, as well as parameters for sequencing such as the degree of learner control afforded, the degree of integration among the learning objects, and whether the learner requires remedial or standard sequencing (Merrill & ID2 Research Team, 1996). Remedial sequencing provides pretesting and practice prior to the presentation or exploration interactions, while standard sequencing interactions proceed from presentation through exploration, practice, and assessment (Merrill & ID2 Research Team).

Enact transactions involve actions on the part of the learner that cause learning objects to react through behaviors focused directly back to the user or indirectly through interaction with other learning objects (Merrill & ID2 Research Team, 1996). The number of parameters and values for such transactions is large and complex but manageable through processing by the computer programs associated with the learning system (Merrill & ID2 Research Team).

The third component of Merrill and the ID2 Research Team's (1996) instructional transaction theory is the prescriptive theory of instructional design. They describe it as a collection of “rules for selecting the transaction most effective for promoting learning of a given type of knowledge” (p. 3). The rule sets include those for (a) selecting and sequencing knowledge objects; (b) selecting, sequencing, and enacting instructional transactions; and (c) changing conditional parameters to adapt instruction to individual learners (Merrill & ID2 Research Team).

Merrill and ID2 Research Team’s (1996) work sets the foundation for a work process for instructional design in an object-based environment. A design tool that manifests this foundation in its user interface offers to provide a scaffold for the novice designer and brings consistency to the work of the expert.

The Separation of Content from Strategy

Murray (1998) amplifies Merrill and the ID2 Research Team’s (1996) notion of separating content and teaching strategy by proposing that instructional content, teaching strategies, and learning states must be maintained in separate and independent knowledge bases. Murray proposes that five principles form the foundation of a knowledge base approach to the development of instruction:

1. Content and strategies are to be represented separately.
2. Content must be modularized into discrete units for reuse.
3. Generic teaching strategies must be formulated that may be independently applied to different content. This proposition is aligned with Chandrasekaran’s (1989) ideas about generic task structures.
4. Abstract pedagogical entities (e.g., topics must be explicitly represented and characterized).

5. The design process must occur at the pedagogical level, not at the media level.

The knowledge base approach to the development of instruction offers specific advantages to the designer (Murray, 1998). One such advantage is that since strategies are not embedded in the content, but are discrete entities, it is easier to identify and modify them. Another advantage is that the supporting features of a knowledge object, that Quinn and Hobbs (2000) identify as related components of a learning object, may assume a formalized structure that make them easier to identify, create, and modify. Those features include elements related to (a) how the object is to be taught, (b) how the object is to be summarized, (c) specific examples of the object, (d) the introduction of the object, and (e) assessment items for the object. Furthermore, Murray suggests that the knowledge base approach allows the production of learning objects that are more learner-centered than other approaches.

Merrill (in press) suggests that an approach expressed as component design theory provides a metacognitive strategy for ensuring that the primary elements essential to effective instruction are addressed in its design. He further suggests that the instructional design approach embodied by component design theory is desirable because it promises improved performance of the task in support of teaching effectiveness, efficiency, and accuracy (Merrill).

The foundation of component design theory is its application of the concept of knowledge objects in the construction of discrete units of information (Merrill, in press). One may approach the organization of knowledge in this way by thinking of a type of container that may

1. Name, describe, or illustrate some entity.

2. Name, describe, or illustrate parts of an entity.
3. Identify properties of an entity, part, action, or process.
4. Identify actions associated with an entity.
5. Identify processes that modify the entity.
6. Identify kinds of entities, actions, or processes. (Merrill, in press)

Each knowledge object identified by the instructional designer has as its companion a knowledge base (Merrill, in press). The knowledge base contains a collection of specific examples of the more generalized knowledge object. The more complex or multifaceted a knowledge object proves to be, the greater the number and greater the variety of examples required to support it (Merrill). This idea is strongly related to Bareiss' (1989) exemplar model of cognitive structure.

Merrill (in press) proposes that the "primary role of the instructional designer is to determine these granular knowledge components and their sequence" (p. 2). The instructional designer approaches a holistic body of knowledge on the desired topic of instruction as material to be broken up into discrete knowledge objects (Merrill).

Learning Strategy Requirements for Component Centered Design

Component centered design theory contains specific requirements for instructional strategies. All strategies must include both presentation and practice elements (Merrill, in press). The presentation and practice modes used for a specific knowledge object depend on which of two information levels–general or specific–to which they belong. General information includes definitions, categories, steps in a procedure, material about a topic, and lists of events. Specific information illustrates instances of a concept, demonstrations of exact procedures, or visualizations of unique processes (Merrill). The choice of which of the two presentation modes is appropriate for any knowledge component is determined by which type of information, general or specific, is to be presented. Merrill suggests that general information is best presented in the telling mode. Information is presented to the learner through language in declarative form. Specific information, however, is best transferred through the showing mode according to Merrill. Exact sequences and procedures in this mode are demonstrated in real and authentic contexts for maximum effect (Merrill).

Component design theory further requires that instructional strategies include opportunities to practice new knowledge (Merrill, in press). As he does with information types, Merrill divides practice opportunities into two modes. The first mode, *asking*, is the most appropriate approach for practicing information delivered in the tell mode. It is used to get the learners to recall newly acquired information by requiring them to remember the information in the context of the question. The second mode, *doing*, is an appropriate strategy for getting the learner to recall specific information. The learner is required to analyze an instance involving the new knowledge, find the properties, categorize features, perform procedures, troubleshoot, design, or predict the outcomes of sets of circumstances regarding the new knowledge (Merrill).

The four concepts (a) tell, (b) show, (c) ask, and (d) do express the essence of component design theory in the form of an overarching framework. An important feature Merrill (in press) stresses regarding component design theory is the idea that the knowledge components cited above can be embedded into a number of different instructional architectures, making the theory adaptable to the specific characteristics of a given technology.

Instructional Strategies

Ausubel (1968) proposes as an epistemological tenet that “The assimilation and integration of knowledge is contextual" (p. 185). He uses the term *organizer* to identify one method of facilitating the integration of new knowledge into the learner’s cognitive structure with a contextual foundation (Ausubel). He explains the importance of organizers in this way: "The availability of a relevant superordinate proposition in cognitive structure also enhances meaningful retention by decreasing the rate at which the original disassociability strength of the material declines by decelerating the rate of obliterative assimilation" (Ausubel & Fitzgerald as cited in Ausubel, p. 174). The organizer's function is to provide anchor points, foster relevance, and promote discriminability as a construct for bridging the gap between new and existing knowledge (Ausubel).

Anchor Points in Cognitive Structure

Ausubel (1968) describes two types of information organizers. Expository organizers provide the learner with what Ausubel calls relevant proximate subsumers, which are superordinate to new information. The relevant proximate subsumers are anchor points of familiar information that provide the framework over which new information is bridged into the cognitive structure in a subordinate position. Comparative organizers integrate new knowledge with similar concepts but emphasize the discriminating features of each to differentiate between new and old ideas that appear similar, but are different (Ausubel).

Ausubel (1968) emphasizes the critical role relevant proximate subsumers, or anchor points, play in the effectiveness of organizers by asserting that an organizer whose anchors are poorly established in the learner's cognitive structure may actually be worse for learning similar concepts than having no organizer at all. The anchor must provide unambiguous clarity and stability in order to be useful for discriminating among new propositions similar in nature (Ausubel). Anchors may assume greater stability through the use of the organizer because their position in the knowledge structure and their relationships to one another, or significance, is enhanced through the illustration (Ausubel). Ausubel suggests that advanced comparative organizers are more effective than direct material comparisons because they present the learner with all the material from a broader, more contextualized perspective.

The number of relevant anchors also improves the likelihood of retention of new propositions since the strength of relevance for any particular propositional relationship is likely to vary with the individual learner (Ausubel, 1968). More relationships increase the likelihood of the learner finding sufficiently strong relevance in enough of them to assure retention of the new proposition (Ausubel). Additionally, a rich selection of anchors for new information improves the discriminability of the construct to differentiate more finely among similar propositions in the learner's cognitive structure (Ausubel). There is, however, a hazard to introducing an organizer whose knowledge structure is either too detailed or not sufficiently relevant because doing so may trigger a closure or shutting off of that line of inquiry (Smedslund as cited in Ausubel).

The Importance of Knowledge Hierarchy to Instructional Strategy

Ausubel (1968) proposes that considerable effort must be devoted to identifying the most basic organizing concepts of a topic, because they assume the role of highest relevant proximate subsumers. A process of progressive differentiation, narrowing focus from the general and most inclusive to the most detailed and specific in an organizer, reflects the "natural sequence of acquiring cognitive awareness and sophistication" in the learner (Ausubel, p. 190). Ausubel finds this to be in conflict with common instructional practices where homogenous clusters of topics are addressed in sequence without regard to level or inclusiveness of concepts and the cross-referencing of related ideas is a task left to the learner.

Ausubel (1968) identifies four specific problems with the traditional approach. First, the learner is often introduced to multiple terms for what is essentially the same thing presented in different contexts. Second, the artificial separation by topic and other arbitrary barriers such as course sequence places distance between closely related concepts that deter the recognition of commonalities. Third, because the learner is introduced to information in haphazard sequences of cognitive levels–subsumption of lower order propositions under higher order–clearly fixed anchors is difficult to achieve. Finally, concepts that are significantly different lack subsumers of sufficient discriminability and are erroneously fixed into cognitive structure as identical propositions; or, because the discriminability of the subsumer is weak, the distinction between two similar concepts fade over time until the two are recalled as the same thing (Ausubel).

Integrative reconciliation is a term Ausubel (1968) uses to describe a dimension of the subsumption process. He suggests that there are three common responses to contradictions between existing knowledge and new propositions. One response is the outright rejection of the new material as meaningless or erroneous. Another is the compartmentalization of the new information apart from the rest of the learner's cognitive structure. An example of such compartmentalization would be the rote memory of a list of steps in a procedure that otherwise makes no sense or has no context. Finally, Ausubel proposes that integration of the new knowledge may occur through the adoption of a more inclusive relevant proximate subsumer. In such a case, an alternate cognitive anchor point emerges that provides a stronger bridge to the new information than the original anchor. He suggests that organizers aid the process of integrative reconciliation by explicitly identifying similarities and differences between new and old knowledge (Ausubel).

A feature of organizers that supports reconciliation is their ability to provide sequential structure (Ausubel, 1968). Ausubel comments that "natural sequential dependencies among the component divisions of a discipline . . . constitute specifically relevant ideational scaffolding for the next item in the sequence" (p. 195). He stresses the importance of a separate organizer for each instructional unit for fixing new material to a previously established ideational anchor. While sequence may depend a great deal on the availability of good anchors, Ausubel cites Gagne (1965) to support his assertion that the exact sequence of an organizer is critically important to ensure the prevention of errors in understanding brought about by skipping essential steps.

Strategies for Mastery of New Material

Consolidation is another dimension of the subsumption process as described by Ausubel (1968). He defines this as mastery of new material through overlearning accomplished by three measures.

The first of these measures is adequately spaced repetition and review. Ausubel (1968) suggests that repetition of new material administered in a block of time too concentrated and too close to the initial introduction of a concept is less effective in facilitating consolidation than spreading out repetitive practice opportunities and reviews over time.

A second measure is the application of "sufficient intra-task repetitiveness prior to intra- and inter-task diversification" (Ausubel, 1968, p. 197). A proposition must be sufficiently practiced to bridge it firmly to its subsumer before new relationships or new propositions are introduced.

The third measure is to ensure opportunities for differential practice of difficult components. As a difficult concept is practiced, over time, more difficulty and complexity is introduced until the desired level of mastery is achieved.

Ausubel (1968) emphasizes that since better performance is the result of enhanced discriminability, frequent testing and feedback requiring increasingly fine discrimination among alternatives of varying degrees of correctness is desirable.

Ausubel's Cognitive Style Continuum

The cognitive style of the learner serves as yet another dimension of Ausubel's (1968) model for integrative assimilation of knowledge. He concedes that there are consistent and enduring differences among individuals that are manifested in their cognitive organization and thus in their cognitive functioning (Ausubel). Learners assume a place along a continuum of styles with what Ausubel describes as generalizers at one end and particularizers on the other. Perception, information processing, and storage are the variables whose values are combined to place learners along this continuum. Generalizers transform information by describing it in the context and from the perspective of existing anchors, while particularizers select certain key discrimnant details to distinguish new knowledge from existing knowledge (Ausubel).

Metacognitive Strategies

West et al. (1991) group metacognitive strategies for organizing information in the design of instruction into four broad categories. Each of these four categories, chunking, spatial, bridging, and general purpose, address some method for establishing relationships among knowledge elements.

Chunking strategies break a body of information up into smaller units, or discrete chunks (West et al., 1991). This enables the information to be manipulated into sequences and for relationships among the chunks of information to emerge. The sequences and relationships become metainformation about the material that can support its integration into cognitive structure and aid its accessibility in the future (West et al.). Such a strategy establishes the groundwork for the concept of the knowledge object, which is one of the fundamental elements of this study.

Spatial metacognitive strategies exploit the physical relationships among a body of discreet units of information as they are presented to the learner for integration (West et al., 1991). The distances and relative positions of information organized in a pattern become a tool for integration and recall. These strategies fall into three subcategories: (a) Type 1 frames, (b) Type 2 frames, and (c) concept maps (West et al.).

Type 1 frames are in the form of a matrix in which both columns and rows have headings containing the names of concepts, categories, or relationships (West et al., 1991). Type 1 frames are flexible learning tools in that the boxes formed at the coordinates of a row and column may be filled with the appropriate information (a) by the instructional designer before the learner sees it, (b) by the instructor in the presence of the learner as part of a presentation, or (c) by the learner working either independently or collaboratively (West et al.).

Type 2 frames feature the same matrix design as Type 1 frames, with row and column headings labeled with the names of concepts, categories, or relationships, but certain key coordinate boxes, or frames, are filled out in advance (West et al., 1991). The learner is expected to use the relationship of the row and column headings and provided coordinate cell contents to infer the contents of remaining blank coordinate cells (West et al.).

Concept maps illustrate the relationships among associated concepts by graphically arranging them and drawing connectors between them that describe the relationships (West et al., 1991). Groupings, physical distances, and relative vertical and horizontal position represent the structural pattern of the information (West et al.).

Bridging metacognitive strategies facilitate links between information already existing in cognitive structure and new knowledge (West et al., 1991). West et al. identify three types of bridging strategies: (a) advance organizers, (b) metaphors, and (c) Type 2 frames.

Advance organizers are combinations of very brief summaries of relevant prior knowledge and outlines of the new concepts to be introduced (West et al., 1991). The summary serves as a bridge, or to use Ausubel's (1968) term, *relevant proximate subsumer*, to the new knowledge to be introduced and draws attention to important relationships between old and new information (West et al.).

Metaphors, analogies, or similes are generalized connotations of new concepts in the terms of older, more familiar ones (West et al., 1991). The meanings and relationships of the new information are transposed into similar structures and relationships in the more familiar one, thus enabling the learner to make general predictions about the outcome of interactions among new elements by following the model of that type of interaction in the more familiar case (West et al.).

Type 2 frames also serve as bridging strategies for some applications, as well as for spatial strategies. Bridging occurs through the partially completed grid of a Type 2 frame. The information present in the coordinate cells and its relationship to the concepts represented in the row and column labels enable the learner to infer the appropriate information to be entered in remaining, empty coordinate cells (West et al., 1991).

Finally, West et al. (1991) address general-purpose cognitive strategies. This category is represented by three subcategories: (a) rehearsal, (b) imagery, and (c) mnemonics.

Rehearsal strategies represent a range of methods that simply allow time for the learner to be actively engaged with the new material in ways that elicit performance

(West et al., 1991). Asking and answering questions, summarizing, and predicting the outcome of scenarios based on the new knowledge are examples of rehearsal strategies (West et al.).

The other two general-purpose strategies focus on what West et al. (1991) suggest are two important information-encoding processes. They suggest these processes, image encoding and verbal encoding, are very dependent on the richness of experience possessed by the learners using them.

Imagery strategies employ the mental visualization of objects, events, and combinations of those elements (West et al., 1991). This mental snapshot of a set of propositions is similar to the concept mapping technique in the suite of spatial strategies, but the imagery is usually representative of the real world expression of the knowledge element and its place in the scene of its application (West et al.).

Mnemonics exploit the verbal encoding process embraced by theorists such as Schank and Abelson (1995) to construct verbal strings or acronyms or to employ letter coding to produce higher order cognitive structures (West et al., 1991). These structures, which are smaller than the robust clusters they represent, may then be accessed by the learner and folded out or exploded to recall the more robust cluster of concepts attached to it (West et al.).

Cognitive Apprenticeship as Instructional Design Strategy

Iterative cycles of instructional design have seldom been applied in practice because of designer sensitivity to cost and time constraints (Wilson, Jonassen, & Cole, 1993). Ill-defined content domains or diverse populations present problems that reveal the limitations of linear instructional design processes (Wilson et al.). Wilson et al. suggest that instructional design models become internalized by instructional designers as schema for performing the design tasks and that specific details about the process become less consciously present over time.

Wilson et al. (1993) note a paradox raised by the advancement of technology into the workplace. While the adoption of technology has increased the demand for highly developed skills and specialized knowledge, the automation of basic tasks and lower level work has eliminated entry level positions that previously enabled an apprentice to develop the more specialized knowledge and advanced skills over time under the supervision of a more skilled and experienced worker (Wilson et al.).

The Collins, Brown, and Newman (as cited in Wilson et al., 1993) model of cognitive apprenticeship summarizes how technology can help provide the benefits of traditional apprenticeships in eight principles:

1. Content. Teach tacit, heuristic knowledge in addition to textbook knowledge.
2. Situated Learning. Teach knowledge and skills in contexts that reflect the way the knowledge will be useful in life.
3. Modeling and explaining. Show how a process unfolds and tell reasons why it happens that way.
4. Coaching and feedback. Observe students as they try to complete tasks and provide hints and help when needed.
5. Scaffolding and fading. Support learners by performing parts of the task they cannot perform, gradually reducing the support as the learners develop more skill.

6. Articulation and reflection. Have students think about and give reasons for their actions, thus making their tacit knowledge more explicit.
7. Exploration. Encourage learners to try out different strategies and observe their effects.
8. Sequence. Proceed in an order from simple to complex with increasing diversity.

The Technological Dimension

The technological foundation for a grounded learning object-based instructional design tool addresses the influence that technology may have on the types of possible learner-system transactions (Hannafin & Land, 1997). Both the way that learners should be able to interact with the technology and the nature of the support the technology should provide to the learner are elements of interest. Another is the way that knowledge is collected, organized, and manipulated for learning with technology. A third element of interest is the culmination of technology-based, knowledge-organizational schemes in the concept of the reusable learning object and models for instructional design that incorporate it. The reusability of learning objects is dependent on the ability of designers to efficiently identify and locate the objects. Thus, a fourth element of interest is the range of methods for developing metadata about learning objects. A final element is a development and implementation methodology for technology-based tools. The computer science field of knowledge-based expert systems has a long history of developmental experience with these issues in a very similar context and provides a source for insight to their resolution.

Performance Support

Gery (1995) uses a comparison between internally developed software applications from large-scale systems and commercially developed consumer software to illustrate the shift in orientation that she suggests all software systems should undergo toward performance-centered design. Gery employs seven points of comparison to illustrate these differences:

1. Assumptions about users' and workplace knowledge.
2. Development priorities.
3. Implementation time frames and expectations.
4. Assumed user characteristics.
5. Design goals.
6. Basis for measurements and rewards.
7. Things for which the developer is not held accountable.

The essence of the comparison is that market-driven consumer software more often exhibits creative solutions to common tasks than internally developed systems and that consumer software is more often intrinsically supportive of task performance (Gery, 1995). Gery proposes that all computer-mediated systems incorporate the best features of commercial software that reduce user support costs by integrating them into the application and incorporating task-centered design into their user interfaces.

Gery (1995) describes three classes of performance support for computer-mediated work tasks: (a) intrinsic support, (b) extrinsic support, and (c) external support. She identifies the property that separates the three classes as the degree to which the support is removed from performance of the task itself.

Intrinsic performance support is "so integrated into the interface structure, content and behavior, and application logic that it is impossible to differentiate it from the system itself" (Gery, 1995, p. 45). In such a case, the performance support is the tool itself.

Extrinsic performance support is also integrated into the computer-mediated workspace. It must, however, be invoked by the user or is presented to the user for acceptance or rejection (Gery, 1995).

Finally, external performance support may or may not be computer mediated, but is never integrated into performance of the task prior to need. It presupposes that the people performing the task both recognize when support is advisable and know how to access it (Gery, 1995).

Gery (1995) proposes that intrinsic support should account for 80% of the support component for any performance-centered system in order to significantly

1. Increase the time the performer is able to devote to the work task.
2. Decrease the cost to develop competent performance.
3. Increase the maintainability of the workspace.

Electronic Performance Support Systems

A performance-centered electronic performance support system (EPSS) must possess 19 attributes that Gery (1995) has synthesized from her evaluation of successful commercial products:

1. Establish and maintain a work context.
2. Aid goal establishment.
3. Structure work process and progression through tasks and logic.

4. Institutionalize business strategy and best approach.
5. Contain embedded knowledge in the interface, support resources, and system logic.
6. Use metaphors, language, and direct manipulation of variables to capitalize on prior learning and physical reality.
7. Reflect natural work situations.
8. Provide alternative views of the application interface and resources.
9. Observe and advise.
10. Show evidence of work progression.
11. Provide contextual feedback.
12. Provide support resources without breaking the task context.
13. Provide layers to accommodate performer diversity.
14. Provide access to underlying logic.
15. Automate tasks.
16. Provide alternative knowledge search and navigation mechanisms.
17. Allow customization.
18. Provide obvious options, next steps, and resources.
19. Employ consistent use of visual conventions, language, visual positioning, navigation, and other system behavior.

Gery (1995) proposes that developers of performance-centered support systems must imbue their systems with the 19 attributes mentioned above with two ultimate goals. First, developers must integrate the knowledge, data, and tools required to be successful in performing a task. Second, developers must provide task structuring support to help performers create their required deliverables (Gery).

Reusable Resources

The emergence of EPSS represents a shift in focus for educators away from delivery models that teach decontextualized knowledge and skills (Hannafin, Hill, & McCarthy, 2000). Organizations and institutions are looking at modularized digital resources that convey relevant knowledge and skills to directly support performance as an alternative to those traditional models (Hannafin et al.). While the EPSS approach differs from traditional models, there is not so much a single design concept as there is a common orientation toward designing systems that employ resources in a supportive function to learning or task performance (Hannafin et al.).

Information and media that are already available make up a large part of resource-based performance support systems, but they are repurposed by specialists, many times, in response to the demands of specific situations (Hannafin et al., 2000). Hannafin et al. suggest that a flexible development and delivery environment enables the resource-based approach to establish quickly the relevance of existing information by redefining resources and situating them in different contexts. They propose that resource-based EPSSs combine four core design components to accomplish these tasks: (a) resources, (b) contexts, (c) tools, and (d) scaffolds (Hannafin et al.).

Resources, or items of core information, are of two types according to Hannafin et al. (2000). Static resources represent fixed recordings of ideas, facts, or beliefs at a specific point in time. Dynamic resources frequently or continually change in character (Hannafin et al.).

Performance Context in EPSS Design

The real or virtual settings framing performance or learning circumstances make up the performance context design component for resource-based EPSS design (Hannafin et al., 2000). The situations and goals that comprise context may be either externally directed by the designer or generated by the learner. The setting of the venue (real or virtual), pace and sequence, as well as interaction facilitation, activity assignment, and goal establishment in externally directed contexts are based on requirements external to the user. Learner-generated contexts involve the unique needs of the individual to define a performance goal that consequently influences the source and type of resources needed as well as the criteria for satisfaction of the individual's need (Hannafin et al.).

Hannafin et al. (2000) divide tools, which enable users to organize and present their understanding, into four categories: (a) searching, (b) processing, (c) manipulating, and (d) communicating. Search tools extend the breadth and capability of available resources, while process tools support the collection, organization, integration, and generation of information. Manipulation tools provide the user the ability to test and act upon ideas. Communication tools, which may be either synchronous or asynchronous, enable the sharing of information (Hannafin et al.).

Scaffolds, which assist users as they engage in learning and performance activities, are divided by Hannafin et al. (2000) into four types: (a) conceptual,

(b) metacognitive, (c) procedural, and (d) strategic. Conceptual scaffolds guide the user in deciding what to consider and in recognizing relationships. Metacognitive scaffolds provide learners with a means of assessing what they know and reducing their cognitive load. Procedural scaffolds focus on facilitating the use to the system itself while strategic scaffolds provide alternative ways to approach a task, including off-loading some tasks to the system (Hannafin et al.).

Knowledge Operations in Technology-Based Tools

Ramsey, Loggia, and Schultz (1989) identify five features as important considerations when choosing the form that knowledge representation is to take in the development of expert systems. They suggest that each feature represents a factor in an expert system’s knowledge expressability (Ramsey et al.).

One important feature is its ease of representation for the particular domains it must express. Examples include the capability of representing objects, events, relationships, concepts, goals, and metaknowledge. Additionally, its ease of accommodating preexisting formats for knowledge in particular domains is a feature Ramsey et al. (1989) consider important.

A second feature important in choosing a knowledge representation formalism according to Ramsey et al. (1989) is its efficiency of space and time. They stress a need for the concise formulation of knowledge and the minimization of the processing required to accomplish that formulation.

The ease of human understanding also plays a role in knowledge representation design (Ramsey et al., 1989). A user must be able to read efficiently, evaluate the correctness, and evaluate the completeness of knowledge. The representation format must have a means for easily encoding new knowledge, as well as maintaining old knowledge. A modular approach is often desirable (Ramsey et al.).

A fourth factor in evaluating the form of knowledge representation to be used in an expert system is the relationship between the knowledge base and inference engine. Ramsey et al. (1989) suggest that the types of inferences used in the expert system restrain the kinds of possible representation as well as limit the range of suitable data structures.

Finally, the ability of the knowledge representation model to deal with uncertainty plays a role in its suitability for an expert system. Ramsey et al. (1989) suggest that desirable formalism must be able to address varying levels of uncertainty.

One graphical knowledge representation model Ramsey et al., (1989) discuss is the use of frames. The frame model provides descriptive information about a particular topic. Each frame contains a single, discreet unit of information. Several frames may be arranged in vertical or horizontal rows, which Ramsey et al. called slots, according to a particular descriptive value. Slots help to define valid types of information or the range of types that belong to the row. The descriptive value for one slot may connect more than one frame set together into a larger structure. Ramsey et al. provide three terms to classify descriptive information for the frame model. A *stereotype* is the term for a class of objects. A *prototype* is characterized by a list of statistics and specifications that are applicable to a class of objects. An *instance* is a list of unique details for each individual information object. Ramsey et al. propose that frames excel at aiding the reasoning process from classifying observed facts to arriving at best explanations based on that classification process. Frames represent descriptive knowledge well and are efficient search tools, but Ramsey et al. find fault with the completeness of the frame model because it lacks a formal way to deal with the subsequent results of the classification and descriptive processes.

Ramsey et al. (1989) offer the concept of scripts as more satisfactory knowledge representation models than frames. Scripts, as Ramsey et al. describe them, are similar to frames but include the notion of sequence and categorize common series of events into stereotypical sequences. Prototype scripts represent frame slots that are filled at the time of instantiation with the details of a series of events. A collection of prototype scripts may be combined into a scene, the outcome of which may invoke other scripts. Certain preconditions for each script trigger the script's activation. Each script may also possess smaller, more specialized components, such as roles or props (Ramsey et al.).

The attraction of scripts for Ramsey et al. (1989) is that they provide a very natural representation and organization of descriptive knowledge that is centered around situations or events. Ramsey et al. do, however, recognize that scripts' usefulness is limited to common events that have been experientially agreed upon by the user group (Ramsey et al.).

Ramsey et al. (1989) propose that the optimal knowledge representation model for expert systems is probably a hybrid of rule, frame, and script-based schemes. They suggest that the mix of each element is best determined by the performance context of the tool.

Organizational Context as a Factor in Knowledge-Based System Design

Colbert, Long, and Green (1990) examine methods required for the development of knowledge-based systems within organizations. They describe a method as a term used in computer programming for units of code written to perform a task. Furthermore, they refine and apply a very precise definition to the term *method* as a "representation to a goal-possessing user with control knowledge for performing a task, meeting certain criteria, using certain instruments, in a given organizational context" (Colbert et al., p. 123).

The Colbert et al. (1990) definition for a method in knowledge base systems provides a convenient framework for the discussion of particular considerations they suggest are important to the success of such a tool. The notion that a method is a representation suggests that care must be taken in determining exactly how it is made available to the user. The coordination of interface properties and situational contexts offers a means for enhancing the effectiveness of the method within the knowledge base tool (Colbert et al.). Furthermore, the characterization of the intended user of the system must not only take the user’s skill level into consideration, but also factor in elements such as user experience, attitudes, preferences, and domain of expertise to define the requirements of a method (Colbert et al.).

Another consideration in the development of methods for knowledge base tools is the nature of the control knowledge itself (Colbert et al., 1990). Control knowledge, the content for the tool, may be procedural in nature or declarative. The level, or specificity, of the control knowledge determines the degree of freedom the developer has in its implementation. The higher the level, or more generalized the knowledge, the greater freedom the developer has in its representation. One dimension of expression for knowledge level is a continuum representing the level of certainty from uncertain to certain. Uncertain control knowledge, or heuristics, permits greater freedom in its implementation than certain control knowledge such as algorithms (Colbert et al.).

Colbert et al. (1990) suggest that knowledge base method developers must also address the question of how specific the goal of the task should be. They note that the level of specificity of the goal of the task does not always bear a direct relationship to the complexity of the method designed to address it (Colbert et al.).

The organizational context in which the method is developed is characterized by elements such as (a) the prior experience of the developers, (b) the attitude of the users toward training, (c) the degree of importance confidentiality plays in professional development opportunities within the organization, and (d) the consequences of any changes in user performance brought about by adoption of the method (Colbert et al., 1990).

Special Constraints on Knowledge Base Tool Development

Colbert et al. (1990) describe some constraints and issues related to the development of knowledge base methods. They propose that the manner in which method designers address these elements defines the balance the developers seek between the possible and the practical (Colbert et al., 1990).

One constraint method developers face is the specification of features for the method. Ill-defined features not only set the stage for complications and delays further into the development process but also affect the completed method’s usability.

Furthermore, Colbert et al. (1990) note the cascading negative effect of an ill-defined feature in a method upon which other features (and even other methods) in the tool are dependent. They also note that the specifications of the whole system may be highly constrained by the values of just a single feature (Colbert et al.).

Another constraint on the development of a knowledge base method Colbert et al. (1990) identify is related to the type of control knowledge that the method is to provide the user. Algorithmic control knowledge presents the user with unambiguous cookbook-like procedures or propositional constructs. The method developer provides a comprehensive, self-contained body of knowledge that the user requires to perform the method's task. In contrast, Colbert et al. (1990) suggest that heuristic control knowledge poses a much more difficult challenge to the method developer. Control knowledge that is heuristic requires a method that must be both iterative in nature and able to provide the user a means of recovering from error (Colbert et al.).

Colbert et al. (1990) draw the conclusion that the less well-defined the task that is the subject of the method and the more heuristic its control knowledge is, the more skilled the user must be and the more likely it is that the user will require training in order to use the tool effectively. They suggest that fixing the precise point in the continuum between heuristic and algorithmic control knowledge is an important issue in the development of a knowledge base method. A method's flexibility and cost to produce are both affected by the decision about exactly how algorithmic a method must be (Colbert et al.). Merrill (1997) approaches the issue of design variability by exploiting the notions of generic tasks proposed by Chandrasekaran (1989) to present the designer with a limited set of strategies determined by the tool's designer to be most appropriate. Merrill defines a learning-oriented instructional design tool as one that "has built-in instructional strategies which are based on scientifically verified principles of instruction" (¶ 1). Such a system includes a library of preprogrammed, built-in instructional strategies that the designer selects to accomplish the learning goal (Merrill). Merrill identifies as disadvantages the possibility that the designer may disagree with the instructional design theory built into the system, as well as the fact that although there may be a limited number of scientifically validated instructional strategies, the number of ways they may be applied is nearly infinite.

Another issue Colbert et al. (1990) identify as significant for knowledge base method developers is one of finding the appropriate balance between a method's strength and its complexity. Colbert et al. suggest that a method's strength is in part determined by the degree to which it incorporates multiple sources of knowledge. On the other hand, they note that hybrid methods increase the complexity of the issues in developing the methods such as cross purposes, conditions of use, and algorithmic specificity.

The Problem of Knowledge Elicitation

Cooke (1994) amplifies an important development issue described by Colbert et al. (1990), design variability, by proposing that in the development of expert systems, verbal reports from subject experts regarding their problem-solving processes are not only difficult to produce, but are also frequently inaccurate and biased. According to Cooke, one avenue expert systems designers may take to reduce inaccuracy and bias is to employ descriptive statistical techniques to fix expressions of relatedness systematically. Multidimensional scaling and cluster analysis are two such techniques. They generate structural representations for items in which the distance between each item represents the degree of relatedness among them (Cooke). Such techniques do not, however, elicit the initial domain-related concept set, and Cooke warns that the complete set of concepts is the only way to avoid context bias in defining the domain.

While Cooke (1994) notes that it is more efficient to use the most appropriate source, or expert, for the initial set of ideas, even the expert’s notion of comprehensiveness is often in error. Furthermore, since free recall produces less information from domain experts than processes that produce recognition from cues, Cooke suggests that models using organizational aides are most effective for eliciting knowledge.

Jackson (1999) expands Cooke’s (1994) focus on the collection of content for knowledge-based tools and identifies five stages of knowledge acquisition in the development of expert systems: (a) identification, (b) conceptualization, (c) formalization, (d) implementation, and (e) testing. Identification delineates the class of a problem, a data set, or criteria for a solution to a problem. This stage also reveals more complex information such as resources available, models of cooperation, or models of expertise (Jackson). Conceptualization uncovers key concepts and the relationships among them. It also includes the characterization of data, flow of information, and the structure of domains (Jackson). Formalization is an attempt to characterize the nature of a knowledge base’s underlying search space. The process is used to establish the certainty and completeness of information as well as to establish constraints, such as time (Jackson). The implementation stage of knowledge acquisition establishes the specifications of control structures and information flow. Data structures are defined and the degree of information module independence is characterized (Jackson). The testing phase of knowledge acquisition in expert systems involves using large representative samples to look for missing, incomplete, or wrong rules (Jackson).

Analysis Models for the Development of Knowledge Base Tools

Jackson (1999) proposes that all expert systems must define (a) a problem, (b) a function, and (c) tasks to be completed by the tool. He also suggests that it is important for the tool to employ models to execute these work processes (Jackson). He suggests that (a) the organizational model employed in an expert system establishes the socioeconomic environment of the application, (b) the application model identifies the problem to be solved and the function to be fulfilled by its solution, and (c) the task model breaks behaviors associated with the function down into their component tasks (Jackson).

Jackson (1999) identifies five layers of analysis that he suggests are important in the development of expert systems: (a) knowledge conceptualization, (b) epistemological analysis, (c) logical analysis, (d) implementation analysis, and (e) ontological analysis. Knowledge conceptualization involves determining a formal description of knowledge, identifying primitive concepts, and describing the range of conceptual relations to be addressed by the tool. Epistemological analysis attempts to uncover the structural properties of conceptual knowledge as in the identification of taxonomic relations among concepts. Logical analysis develops information about how the tool is to perform reasoning tasks within the tool’s knowledge domain. Implementation analysis develops the mechanisms upon which the first three analyses are based by resolving specific interaction details. Finally, ontological analysis defines the overall conceptual framework of the expert system (Jackson).

The ontological analysis itself is divided into three dimensions: (a) static, (b) dynamic, and (c) epistemic (Jackson, 1999). The static ontology analysis identifies what specific knowledge domain entities are to be addressed by the tool, as well as their properties, and characterizes the relationships among them. The dynamic ontology analysis defines the states that occur in problem-solving processes and describes the manner in which one state may be transformed into another. The third and final ontological analysis, the epistemic one, describes the knowledge that guides and constrains state transformation (Jackson).

Letson (2001) addresses Jackson's (1999) static ontological analysis by suggesting that a human-like understanding of words, concepts, and categories in computer systems remains a distant goal. Nevertheless, he proposes that organizations are struggling to identify and extract useful data from immense quantities of unstructured data and are exploring taxonomy technologies as possible solutions (Letson).

Taxonomy technologies address the organization of large quantities of data by applying algorithms that sort data through computational analysis of patterns within the data itself (Letson, 2001). Taxonomic algorithms are distinguished by four approaches to the sorting process they apply to the content under analysis: (a) rules based, (b) statistical analysis and pattern matching, (c) linguistic analysis, and (d) ontologies (Letson).

Rules-based taxonomic systems utilize sets of keywords and logical relationships to analyze and sort documents. The rules are typically designed by human experts, but may also be developed through analysis of a representative sampling of source documents (Letson, 2001).

Statistical analysis and pattern-matching approaches sort documents based upon the presence, frequency, and relative location of terms in the documents (Letson, 2001). The sorting may group documents either into patterns that emerge naturally or into patterns derived from model sets of documents assembled to reflect a predetermined organizational model (Letson).

Linguistic analysis focuses on the structural form of expression or use of language from a semantic perspective in documents (Letson, 2001). Most approaches then apply a statistical analysis of the semantic groupings to validate patterns or determine significance (Letson).

Ontologies impose a predetermined human-developed structure on document collections to bring them into organizational conformance with it (Letson, 2001). Such systems include information about the relationships among their structural components, and documents are analyzed for similar relationships (Letson).

Taxonomic Systems for Knowledge

Letson (2001) proposes that the evaluation of taxonomic systems for adoption should include seven criteria. One such criterion is the degree of accuracy and reliability the category assignments in the system exhibit. Another is the proportional mix of automated and human involvement in the classification process for the application. A third criterion examines the flexibility of the system and the degree to which it can be fine tuned for a specific application. A related criterion is the degree to which the tool can identify new items or relationships and either self-adjust or prompt the user to make a decision regarding its discovery. Some organizations may be particularly interested in determining the degree to which a taxonomic application can integrate with existing data organization models. A sixth criterion may be the scalability of the application, particularly if the organization is interested in implementing it in phases, or if the amount of data to be organized is expected to significantly grow. Finally, the degree of customized or personalized presentation of data to the user may be a factor in a tool's adoption by an organization (Letson).

Yacci (1999) also relates that organizations have come to recognize that information assets are critical commodities that distinguish one competitor from another. He suggests that the degree to which an organization's knowledge assets are reusable leverages the value of those assets and increases the competitiveness of the organization (Yacci).

Two common problems in addressing the reusability of knowledge intended for instruction are identified by Yacci (1999). Many instructional resources are produced with highly specialized features that are integral to the resource. Such customization limits the range of situation in which the resource may be reused without disrupting the coherence of the instruction (Yacci). Another reusability problem stems from situations in which important details about the subject of the resource frequently change. The fluid nature of the information contained in the resource reduces the number of times it may be reused before it must be modified (Yacci).

Parallels are drawn by Yacci (1999) between a data warehouse, commonly used by organizations for decision support and analysis, and the concept of a knowledge warehouse. The knowledge warehouse contains knowledge components that are accessed in either their original form, just as reports and other predefined views in a data warehouse are accessed, or through ad-hoc queries across multiple original sources (Yacci).

Yacci (1999) attempts to clarify the distinctions between the three terms *data*, *information*, and *knowledge* by first drawing the analogy of data as atoms, the smallest discrete units of knowledge. Information represents organized, sorted, and summarized data in Yacci's model. Finally, he characterizes knowledge as "information combined with context and experience" (Huang, Lee, & Wang as cited in Yacci, p. 6).

The distinctions among the terms data, information, and knowledge reflect an issue having to do with the suitable level of granularity in knowledge classification (Yacci, 1999). Yacci suggests that the reusability of knowledge components is impractical if they are decomposed beyond the defined term for knowledge–information combined with context and experience. Furthermore, Yacci stresses that standardized classification schemes are critical to knowledge component reusability.

Knowledge components that Yacci (1999) proposes as useful in the design of instruction include (a) generality, (b) example, (c) explanation, (d) practice items, (e) test items, (f) overviews, (g) advance organizers, and (h) analogies. The generality is a proposition that applies to all instances of a concept or procedure while an example is a specific instance of a concept, procedure, or principal. Explanations address why something works or is done a certain way. Practice items involve the learner actually performing a skill-building task and receiving performance feedback, while a test item permits the learner to demonstrate competency in that skill. Course maps, which are overviews, place the learner’s position in a set of content as a type of verbal or graphic organizer. The overview and advance organizer serve the purpose of providing the learner more abstract representations of new information that is to come. Finally, the analogy uses the comparison of a familiar concept or object with new concepts to characterize the new information in term of its similarities and differences with the familiar concept (Yacci).

Metadata

An issue related to Letson’s (2001) exploration of the application of taxonomic systems to institutional knowledge and to Yacci’s (1999) notions of reusable information in a knowledge warehouse is that of identifying and describing knowledge components so that they may be found efficiently and applied appropriately in a number of contexts. Recker, Walker, and Wiley (2000) note that the Learning Technology Standards Committee (LTSC), a subcommittee of the IEEE organization, does not make any effort to capture aspects surrounding the initial instructional context of learning objects in their Learning Objects Metadata draft standard. They further note that the above-mentioned standard provides no explicit support for the reuse of learning objects within specific instructional contexts (Recker et al.).

Recker et al. (2000) suggest that metadata structures should not only support what they term authoritative data elements: those providing objective descriptions of specific technical or legal information but also information about the origin and intended use of the object. They propose that metadata also include nonauthoritative information about the contexts and surrounding activities for which the object has proven suitable, including the learning community from which it is derived (Recker et al.).

Two difficulties in the development of metadata structures are related to similar problems in the knowledge engineering effort of earlier expert systems (Recker et al., 2000). First, as Cooke (1994) also observes, the process of knowledge elicitation is a labor-intensive effort and experts often have difficulty expressing critical knowledge about their special skills outside the context of the exercise of those skills in the performance of authentic tasks (Recker et al.). The other problem is related to the framing of knowledge. While it is important to describe what something is, an important feature of that description, particularly in the exercise of logical operations, is that knowledge must also be framed by descriptions of what that particular thing is not (Recker et al.).

Quinn and Hobbs (2000) suggest that "there is no overall ontology that accounts for all knowledge" (p.2). They propose that metadata serve an important purpose in communicating the nature of the knowledge contained in a given learning object. Quinn and Hobbs define metadata as information contained in a learning object that describes the content of the object, what the learning object is supposed to teach, and what requirements there are for its use.

The Evolution of Metadata Standards

The section of a learning object stored electronically that contains the metadata information (the metatag) is formatted according to conventions and practices that have evolved, as Quinn and Hobbs (2000) describe it, into standards that are widely accepted today in the community of developers engaged in the development of commercial and contract learning objects, particularly for the United States government. The current metatag model had its origin in the Dublin Core Metadata Initiative, a 1995 joint project of the National Center for Supercomputing Applications and the Online Computer Library Center, Inc., which first convened in Dublin, Ohio, to develop a sort of library card catalog of the World Wide Web (Quinn & Hobbs). This model consists of fifteen basic descriptive tag elements to be used for the classification of Web documents (Quinn &Hobbs).

The 1997 National Learning Infrastructure Initiative of EDUCAUSE addresses the issue of metatags, but expands the scope of its standards to address a much broader field of activity described as distributed learning (Quinn & Hobbs, 2000). In its Instructional Management System (IMS), now promulgated by the organization called the IMS Global Learning Consortium, Inc., two main goals for IMS are identified:

1. The IMS Global Learning Consortium develops and promotes the adoption of open technical specifications for interoperable learning technology (¶ 1).
2. The Consortium provides a neutral forum in which members with competing business interests and different decision-making criteria collaborate to satisfy real-world requirements for interoperability and reuse (¶ 2).

The Learning Technology Standards Committee of the IEEE has assumed work on the IMS project in order to develop international acceptance of its work through sanctioning by the International Standards Organization (Quinn & Hobbs, 2000).

An important dimension of the evolution of metatag data is the increase in robustness and descriptive capacity of the concept. Where the original Dublin Core implementation involved fifteen rudimentary parameters to describe Web document types, there are now nine distinct categories of tags, each with its own complete hierarchy of metatags, specifications, and parameters (Quinn & Hobbs, 2000).

The comprehensiveness of the descriptive system expands its function from that of document type classification to that of organizational tool for learning objects (Quinn & Hobbs, 2000). The educational tag category, for instance, includes 10 distinct tag groupings: (a) interactivity type, (b) interactivity level, (c) learning resource type, (d) semantic density, (e) context, (f) typical age range, (g) difficulty, (h) learning time, (i) text description, and (j) language. Further divisions appear within each grouping. Interactivity type is divided into active, expositive, and mixed types of interactions. Both interactivity levels and semantic density may be classified as very high, high, medium, low, or very low. Learning resource types are divided into (a) exercise, (b) simulation, (c) questionnaire, (d) diagram, (e) figure, (f) graph, (g) index, (h) slide, (i) table, (j) narrative, (k) exam, or (l) experiment. Typical age range may be expressed as primary, secondary, university, or technical school (Quinn & Hobbs).

The robustness of metadata organizational structure does not only mean that considerable effort and care are required to properly record this information for each object, but it also means that it is possible to assemble a collection of learning objects meeting the specifications of the learning objectives for a particular requirement from many possible avenues of inquiry, just as robust cognitive structure permits access to knowledge elements along many alternate construct paths (Quinn &Hobbs, 2000).

Challenges to Metadata Standards

Two issues in metadata organization present challenges to universal implementation of metatag sytems: (a) granularity and (b) vocabulary. Granularity in the context of learning objects and metadata refers to the discreteness, or size, of a learning object. The finer the granularity, or more discretely an object can be classified, the more specific and precise its application can be. However, each successive level of specificity introduces much greater complexity and sheer amount of data that must be manipulated to produce, store, and access objects organized to this degree. Also, the finer the granularity of the metadata description of an object, that is, the more narrowly defined it is, the less likely it is to be reused in multiple contexts. The granularity of a metadata description is, thus, an issue of determining the point of diminishing returns for the effort required to produce, organize, search for, and reuse it (Quinn & Hobbs, 2000). Quinn and Hobbs use the concept of instruction as an example of the granularity issue. The term instruction is generally understandable in relation to terms such as entertainment or news. However, the term instruction assumes a role termed by Ausubel (1968) as relevant proximate subsumer to a cluster of concepts arranged in a specific sequence. Quinn and Hobbs' notion of instruction is composed of the concepts of introduction, concept, example, practice, and reflection. The introduction activates relevant knowledge. The concept involves the "presentation of the relevant" (Quinn & Hobbs, p. 3). An example illustrates the application of the concept to specific problems. Practice elicits from the learner the application of the concept within an authentic context. Finally, reflection fixes the knowledge into cognitive structure and prepares it for use outside the learning experience (Quinn & Hobbs). Each of these subsumed concepts may be used to support a representation of the concept of instruction, but they may not be used interchangeably to represent each other. A metatag granularity to the level of the concept of instruction may be specific enough for an efficient search, while a granularity of classification more specific than that may preclude objects that would be within an acceptable range of suitability to support the concept (Quinn & Hobbs).

The issue of vocabulary is one that addresses the problem of human variability at the description and query phases associated with metadata (Quinn & Hobbs, 2000). The issue is closely related to the one of granularity in that the less granular, to a certain degree, that the descriptive metadata is, the more widely applicable the learning object may be. The application of standards and limited descriptive vocabulary in the development of metadata narrows the range of human variability to some degree, but cultural and experiential factors may produce a broad range of interpretation for the same term among different individuals (Quinn & Hobbs).

Another issue Quinn and Hobbs (2000) raise related to learning object granularity is that of determining the appropriate size for learning objects. The first stage of the discussion addresses the question of whether any learning object is actually reusable since they are always designed with very specific learners and outcomes in mind. They suggest that learning object size may provide the answer to that question either in the form of a process that finds a natural level for any particular object or through the application of a combination of general guidelines and context analysis (Quinn & Hobbs).

The creation of learning objects, specifically the metadata components for them, is an activity that requires considerable skill in order to achieve both adaptability and coherence (Quinn & Hobbs, 2000). High adaptability is reflected in the combination of small learning objects with very rich metadata. The coherence of a learning object collection is reflected in the similarity of look, feel, and thematic approach among them (Quinn & Hobbs). Quinn and Hobbs predict that the metadata expert will be a professional calling in high demand as the efficiencies of learning object-based instructional development are realized.

Development Methodology

Speed, efficiency, and innovation are desirable features in an instructional design program competing in the modern marketplace. Rapid prototyping addresses the issue of efficiency in instructional design by proposing an alternate strategy for that process (Tripp & Bichelmeyer, 1990). Tripp and Bichelmeyer suggest that the foundation of this alternate strategy is derived from the proposition that the process of design is a matter of finding the best description of the problem and, by extension, “the equivalent to a formal representation of problem-solving heuristics” (p. 32).

Tripp and Bichelmeyer (1990) also note that the design process involves many partial and interim solutions that bear little resemblance to the final design. Furthermore, they suggest that the complexity and unpredictability of the design process poses particular problems in communicating that process to new practitioners. These factors lead Tripp and Bichelmeyer to reject Instructional Systems Design (ISD) as a confusion of the scientific process with the design process and to propose that the focus of design should be on solving problems and synthesizing materials to achieve goals.

A feature of problem solving that Tripp and Bichelmeyer (1990) identify as important is that decisions in the process must often be made without complete information and that it is usually impossible for the designer to identify all possible solutions. They use the term *bounded rationalities* to describe decision making based on incomplete information and suggest that designers must make value judgments within the context of a need for action (Tripp & Bichelmeyer).

Rapid Prototyping as an Instructional Design Process

Tripp and Bichelmeyer (1990) conclude that a model of the design process must necessarily reflect initial conjecture, utilization, and iterative modifications. Such a model would include the use of mock-ups and user testing as part of an empirical methodology: essentially, a model of the system used to design and develop the system itself (Tripp & Bichelmeyer). They propose a model of rapid prototyping for instructional design that stresses overlapping and concurrent processes that are interdependent on one another (see Figure 1).

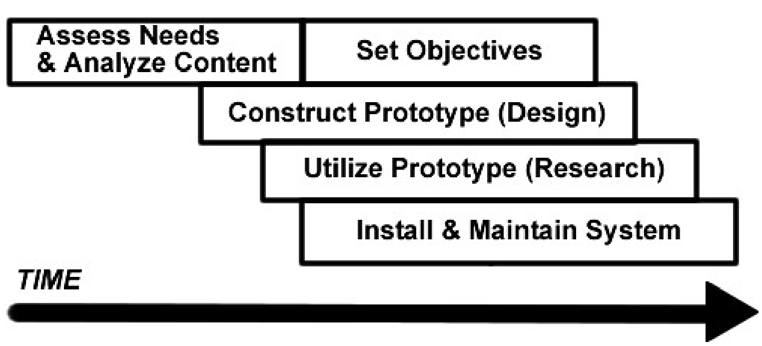

Figure 1. Tripp and Bichelmeyer's rapid prototype model. From "Rapid Prototyping: An Alternative Instructional Design Strategy," by S. Tripp and B. Bichelmeyer, 1990, *Educational Technology Research and Development*, *38*, p. 31.

Needs assessment and content analysis lead to the setting of objectives, but the construction of a prototype, its utilization, and the implementation of the design all proceed in staggered and significantly overlapping stages that require revision and modification throughout the project (Tripp & Bichelmeyer, 1990). The use of rapid prototyping in instructional design requires tools, mostly computer software, that Tripp and Bichelmeyer identify as offering modularity and plasticity. Modularity permits the replacement or substitution of one element for another, while plasticity permits the easy modification of elements while they are in place in the design (Tripp & Bichelmeyer).

Tripp and Bichelmeyer (1990) do caution that while the rapid prototyping model of instructional design may not be appropriate in every case, there are three cases in which they suggest it is a desirable approach:

1. Cases that involve factors so complex that the successful prediction of outcomes is problematic serve as good candidates for rapid prototyping.
2. Cases in which conventional methods of instructional design have produced unsatisfactory results may be better served by rapid prototyping.
3. Finally, cases for which experience with the instructional problem is lacking on the design team lend themselves well to the rapid prototyping model.

Tripp and Bichelmeyer identify both a series of advantages to using the rapid prototyping model and a series of drawbacks to its use. The advantages include

1. It encourages and requires active student participation in the design process.
2. Iteration and change are natural consequences of instructional systems development. Clients tend to change their minds.

3. Clients don’t know their requirements until they see them implemented.
4. An approved prototype is the equivalent of a paper specification, but with the exception that errors can be detected earlier.
5. Prototyping can increase creativity through quicker user feedback.
6. Prototyping accelerates the development cycle.

Disadvantages include

1. Prototyping can lead to a design-by-repair philosophy, which is only an excuse for lack of discipline.
2. Prototyping does not eliminate the need for front-end analysis. It cannot help if the situation is not amenable to instructional design.
3. A prototype cannot completely substitute for a paper analysis.
4. There may be many instructional design problems that are not addressed by prototyping.
5. Prototyping may lead to premature commitment to a design if it is not remembered that a design is only a hypothesis.
6. When prototyping an instructional package, creeping featurism (the adding of bells and whistles) may lead to designs that get out of control.
7. Prototyping can decrease creativity by eliminating the urge to find better designs.
8. Prototyping environments can lead to designs that execute less efficiently than designs instantiated in dedicated authoring languages.

A Cyclical Model for Instructional System Design and Development

Iterative cycles of instructional design have seldom been applied in practice because of designer sensitivity to cost and time constraints (Wilson et al., 1993). Ill-defined content domains and diverse populations present problems revealing the limitations of linear instructional design processes (Wilson et al.).

Wilson et al. (1993) identify six of their own important reasons why rapid prototyping is valuable in computer-based instructional system design:

1. Testing out of user interfaces.
2. Testing of database structure and flow of information in a training system.
3. Testing of the effectiveness and appeal of instructional strategies.
4. Developing templates for the creation of cases or exercises.
5. Creating a concrete model to represent concepts to clients of sponsors.
6. Comparing competing approaches.

According to Wilson et al., there are three fundamental ways computers can help automate the instructional design process: (a) database management, (b) task support, and (c) decision support. Wilson et al. suggest that instructional design models become internalized by instructional designers as schema for performing the design tasks and that specific details about the process become less consciously present over time.

Adelman and Riedel (1997) suggest a model for the development and evaluation of knowledge base systems. The model provides strategies for determining the direction of development of the tool and for systematically identifying potential problems and prioritizing solutions.

Adelman and Riedel (1997) prescribe eight dimensions for defining the character of knowledge base tools before development begins. The intent of the first dimension is to define the kind of knowledge representation employed in the tool. Adelman and Riedel suggest that it is important to denote whether the representations are for declarative or procedural knowledge. Secondly, Adleman and Riedel place importance on identifying the knowledge type, which they divide into surface categories or deep categories. The type of problem the tool is intended to address accounts for Adelman and Riedel's third dimension, which is divided into problems of analysis and problems of synthesis. A fourth dimension is the criticality of the domain; that is, the degree to which the information derived from the tool is essential to the performance of a task (Adelman & Riedel). Defining whether use of the tool is to be optional or enforced is a fifth dimension for characterizing the knowledge base tool. The tool's functionality, specifically whether it is to replace or support existing problem-solving methods serves as a sixth dimension for analysis of the tool. A seventh dimension for knowledge base tool evaluation, according to Adelman and Riedel, is determining the level of interactivity the tool will exhibit. A subdimension in this area is whether the tool is embedded in the work process itself or in other tools or functions in a stand-alone mode. Finally, the user profile serves as the eighth dimension of evaluation for a proposed knowledge base tool. Adelman and Riedel suggest it is important to know whether intended users of the tool will be novices, experts, or a mix of the two.

The Adelman and Riedel (1997) model involves five dimensions:

1. Requirements validation. This dimension examines whether the requirements developed for the system meet user, organizational, and task performance needs. Evaluation questions include
    a. Are the identified organizational and user goals, tasks, and needs accurate, complete, and necessary?
    b. Are the identified functional and system requirements accurate, complete, and necessary?
    c. Is the technology appropriate for the tasks and problems of both the organization and user?
2. Knowledge base validation. This activity assesses the functional completeness and accuracy of the knowledge base. Evaluation questions include
    a. Is the knowledge base logically complete and behaviorally consistent?
    b. Is the knowledge base logically consistent, efficient, and maintainable?
3. Knowledge base verification. The logical consistency and the completeness of the knowledge base are assessed in this process. Evaluation questions include
    a. Is the knowledge base functionally complete?
    b. Does it have acceptable predictive accuracy?
4. Usability evaluation. The ease of use of the knowledge base is examined through such a measure. Evaluation questions include
    a. To what extent does the knowledge base tool interface meet accepted human factors standards?
    b. To what extent is the tool easy to use and easy to learn to use?

c. To what extent does use of the tool decrease workload?

d. To what extent does the tool's explanation capability meet user needs?

e. Is the allocation of tasks between the user and the knowledge base tool appropriate?

f. Is supporting documentation adequate?

5. Performance evaluation. Such an assessment measures the degree to which the knowledge base meets the organizational task and performance requirements. Evaluation questions include

   a. Is use of the knowledge base tools cost effective?

   b. To what extent does the tool meet user and organizational needs?

   c. How effective is the tool in enhancing user and organizational performance?

Adelman and Riedel (1997) divide the approaches to developing knowledge bases into two broad categories: (a) nonprototyping and (b) prototyping. Nonprototyping development models such as the waterfall method usually possess five phases: (a) requirements analysis, (b) requirements specification, (c) design, (d) implementation, and (e) evaluation. Typically, two of the phases, requirements analysis and specification, are completely finished before system design and implementation begins (Adelman & Riedel). Prototyping models, on the other hand, use prototypes of the knowledge base as a working model for iterative revision. Adelman and Riedel suggest such models may go through a five-step process several times before the product is deemed ready for implementation: (a) stimulus for knowledge acquisition, (b) requirements definition, (c) specifications development, (d) user feedback, and (e) expert feedback.

The O’Keefe and Lee (as cited in Adelman & Riedel, 1997) integrative model of expert system verification and validation is an evolution of the prototyping model into a working methodology favored by Adelman and Riedel. They suggest the strength of the spiral model is in the iterative character of the process and evolutionary character of the prototype development and evaluation cycles (Adelman & Riedel).

As shown in Figure 2, each cycle of the development process includes steps for (a) analysis of requirements; (b) verification of requirements; (c) knowledge acquisition; (d) setting acceptable levels of performance; (e) development, modification, or expansion of a prototype; and (f) evaluation of the performance of the prototype (Adelman & Riedel, 1997). Prototypes in each successive cycle increase in functional capability, robustness, and usability. The first simple prototype serves as a means for demonstrating the feasibility of the tool and its main concepts. The prototype developed in the next cycle is a vehicle for researching specific functionality problems and issues that emerge from the previous analyses. A field prototype developed in the third cycle exhibits features and functionality representing most of the intended final form of the tool. It serves to examine usability issues and serviceability within the context of its intended working environment. Finally, a production model emerges from the last round of verifications, analyses, and evaluations (Adelman & Riedel, 1997).

The methods for evaluation of the prototype in each successive cycle increase in rigor, comprehensiveness, and fidelity to actual applications of the tool. The first evaluation is a case test that establishes the soundness of functions related to primary concepts underlying the tool. The next cycle’s field test examines the prototype’s functionality within the context of actual application. A third round of evaluation is an exhaustive mechanical verification and statistical analysis to document a complete picture of the tool’s capabilities. Finally, a control group evaluation provides an in-depth examination of the tool’s practicality and performance as a final opportunity for refinement before the tool’s implementation (Adelman & Riedel, 1997).

One of the methods that Adelman and Riedel (1997) identify as appropriate for application in requirements validation for knowledge base tools is task analysis. Several of the nearly dozen task-analysis methods Adelman and Riedel identify bear further examination as models for eliciting information from people in ways that not only

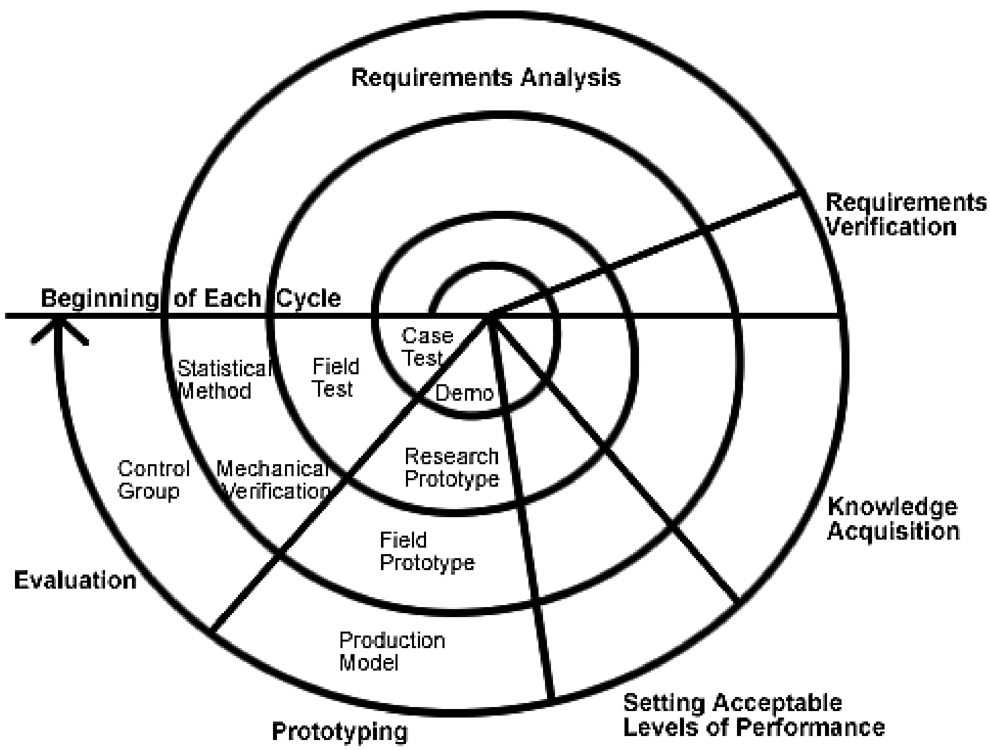

Figure 2. O’Keefe and Lee’s cyclical application development model. From *Handbook for Evaluation Knowledge-Based Systems: Conceptual Framework and Compendium of Methods*, by L. Adelman & S. Riedel, 1997, Boston: Kluwer.

produce knowledge as an output for use in the tool, but also guide the expert in the identification and organization of that knowledge as it is expressed.

Hierarchical task analysis, one of the requirements validation methods Adelman and Riedel (1997) identify, breaks a task into three principal components: (a) a goal or desired state, (b) the task or method used to meet the goal, and (c) the operation or the unit of behavior required to accomplish the task. Another method Adelman and Riedel identify is the use of a questionnaire to depict strength of attitude about selected topics, usually through the use of Likert scales. The critical incident technique identifies important successes or failures related to a task or group of tasks, which then serve as focal points for supporting information, particularly causal and procedural sequences. A related method, the critical decision method, builds on the critical incident model by taking critical incidents and developing concept maps that document the cues and knowledge used by the experts, factors from their previous experiences that came into play, the goals they had in mind during the incident, and the alternatives they considered. The concept maps then serve as discussion points in order for developers and experts to exchange views, correct errors, and identify concept clusters (Adelman & Riedel).

The Cultural Dimension

One important notion regarding the development and implementation of a grounded learning object-based instructional design tool is that it cannot take place in a social vacuum. Institutional leaders, program administrators, instructional designers, production staff, faculty, learners, employers, and community leaders all have an interest in the effect of such an idea on their respective spheres of influence.

Criticisms of the Systems Approach to Instructional Design

Gordon and Zemke (2000) characterize what they identify as a growing dissatisfaction among instructional designers with the systems approach to instructional design. They describe the systems approach to instructional design as a model with six essential steps that must be completed once an organization has determined that there is a training issue and that the performance problem is significant:

1. Determine what the job looks like when it is done right.
2. Analyze the audience, the intended trainees.
3. Design a training course.
4. Develop and fine tune the course.
5. Deliver the course to its intended audience.
6. Monitor and evaluate the course and its results on an ongoing basis.

Gordon and Zemke (2000) summarize the complaints from instructional designers about the systems approach to instructional design into four areas of criticism:

1. ISD is too slow and clumsy to meet today’s training challenges.
2. There’s no *There* there.
3. Used as directed, it produces bad results.
4. It clings to the wrong world view. (p. 44)

Fred Nickols, an instructional designer involved in discussions with Gordon and Zemke (2000) about the impracticality of the ISD model in the modern environment, is quoted as saying, “ISD takes too long, it costs too much and, by the time you’re through, the opportunity you were trying to exploit through training has passed you by” (p. 47). Olcott (1999) suggests that the traditional strategy of deliberation, consensus, and incremental change employed by learning institutions has become ineffective for dealing with the demands of a technology-accelerated culture. Public and legislative forces are applying pressure on education practitioners to be more responsive to increased competition and societal needs (Olcott). Gordon and Zemke emphasize that the driving forces in today's conditions are change and speed. They suggest that training solutions that are less complete and less elegant than traditionally designed solutions but which are implemented at the critical moment are often good enough to meet the immediate training requirement. The problem is not so much with the correctness of the design principles or the learning theories behind them, but with the administrative processes associated with the management of the project. They suggest these processes are too elaborate and involve too many politically vulnerable checkpoints to be efficient in today's market (Gordon & Zemke).

The second criticism, that there is no *there* there, is centered around the idea that the focus of ISD is too much on the process and not on the end result or objective of the process (Gordon & Zemke, 2000). Gordon and Zemke suggest that while many ISD methods do a very good job of describing what good instructional designers do in general, they are not very good at prescribing exactly what designers should do for any given case. They also summarize complaints to the effect that ISD is a representation of what good designers do that has been over simplified for teaching purposes to the point of being too generalized to be helpful for any specific training requirement (Gordon & Zemke).

Gordon and Zemke (2000) characterize the third complaint (that ISD produces bad results) with the suggestion that even when the process achieves its instructional objectives, it produces a standardized homogenous outcome that effectively disables the creativity of the people being trained this way. They suggest, however, that practitioners of ISD more commonly focus on conformance to the process to the extent that measurable outcomes do not play a significant role in evaluating the success of the instructional project and, therefore, become irrelevant (Gordon & Zemke).

The proposition that ISD embraces an erroneous world view is the fourth and final complaint that Gordon and Zemke (2000) summarize. The essence of the charge is that ISD erroneously assumes that the target subjects of an ISD project are less capable people than experts and the process must therefore simplify the design to the lowest possible standard. Furthermore, Gordon and Zemke propose that it is wrong to assume that the tasks currently being successfully performed by recognized experts in the target field are the ones that embody the skill sets needed by new practitioners, especially in light of the rapid pace of change in modern culture. There may, in fact, be no master performers or best practices upon which the designers can model the process (Gordon & Zemke).

Factors Affecting the Adoption of Innovation

Rogers (1995) examines the mechanisms and processes by which changes in practice might proceed or diffuse through a cultural setting. Rogers defines diffusion as "the process by which an innovation is communicated through certain channels over time among members of a social system" (p.10). He breaks his definition into four critical elements and addresses the important characteristics of each one:

1. Innovation.

2. Communication through certain channels.

3. Time.

4. Members of a social system.

Innovation is a property Rogers (1995) describes as perceived newness. The core property of technological innovation is its effect on uncertainty. Technological innovation represents change in the quality of information available to people in the process of solving problems. The effect of this change is a reduction in uncertainty about cause and effect relationships (Rogers). Rogers notes the paradox in the fact that while technological innovation creates uncertainty about its consequences, it reduces uncertainty in the affected technological process itself.

The reduction of cause and effect uncertainty is attractive to the individual and serves as the motivating force to learn about the innovation and make a decision on whether to adopt the innovation or not. The character of the individual’s learning about the innovation is divided into two dimensions: (a) information seeking and (b) information processing. The type of information being sought in this process is either uncertainty-reducing information embodied in the technology itself or evaluation information to help reduce uncertainty about the consequences of the innovation (Rogers, 1995). Related sets of technological innovations that undergo diffusion together, which Rogers calls technology clusters, are interdependent and often proceed as a single object through the process.

Rogers (1995) suggests that information about five characteristics of innovation affects its adoption. The first characteristic is the relative advantage the innovation confers upon the adopter. How much better an innovation is than the preceding idea in reducing uncertainty might be expressed in terms of efficiency, accuracy, cost, or time. Compatibility, expressed as an innovation's consistency with the values, needs, and experiences of the adopters, is the second characteristic. The perception of difficulty to understand or to use embodies the third characteristic, complexity. The fourth characteristic affecting the adoption of innovation is trialability. Rogers describes trialability as the ability to experiment with the innovation with little commitment. Finally, the degree to which the results are perceived by others as advantageous makes up the fifth characteristic of observability. One subcharacteristic that often affects all five main characteristics is the degree of reinvention, or modification, of the innovation the adopter feels compelled to exercise as the innovation is implemented (Rogers).

The second part of Rogers' (1995) definition of innovation is communication through channels. Information exchange in the form of awareness knowledge may occur through a range of means from mass media through direct interpersonal contact. The transfer of ideas most often occurs, however, among individuals who share similar beliefs, education, and socioeconomic status. Rogers characterizes this type of relationship as homophilic. It is in these cases that the communication of innovation is most likely to be rewarding to both participants. The communication of innovation is more problematic when the relationship between communicants is heterophilic–when there is a significant difference between the communicating parties. The problems are especially significant in cases where there are very different skill levels in the area of expertise affected by the innovation (Rogers).

The third critical element of Rogers' (1995) definition of the diffusion of innovation is time. Three parameters involving time characterize its influence over the success of innovation diffusion. One parameter is the measurement of time between the first knowledge of an innovation and its adoption or rejection (Rogers). Another parameter is the measurement of the relative position an individual occupies in the innovation's adoption curve. The rate of adoption of an innovation in a population over time serves as the third time parameter (Rogers).

Five Steps in the Decision to Adopt Innovation

Rogers (1995) describes five steps in the decision process that adopters of innovation follow over time. The duration of each step is not consistent, but their sequence is:

1. The first of these steps is to gain knowledge about the innovation. Potential adopters develop both awareness of the innovation and an understanding of what it is and how it works, often through mass communication channels.
2. The next step is persuasion. Potential adopters form favorable or unfavorable attitudes toward the innovation, typically with the aid of interpersonal communication among peers.
3. Step three involves decision. Potential adopters make a choice to either adopt or reject an innovation.
4. Implementation, the fourth step, involves putting the innovation to use. This step is also the point at which reinvention occurs if the innovation requires adaptation to unique circumstances.
5. Finally, confirmation completes the adoption process. There may be reinforcement of the adoption decision, although negative feedback from the

> implementation phase may culminate in the rejection of the innovation in part or in whole. (Rogers)

The degree of innovativeness a person possesses is a good indicator of where that person would be located on the adoption curve for any given innovation. Rogers (1995) divides adopters into five categories based on their innovativeness: (a) innovators, (b) early adopters, (c) early majority, (d) late majority, and (e) laggards. Two characteristics predict into which adopter group a person may fall. The first is the degree of comfort with uncertainty that a person feels. The second is the person's need for peer support. Rogers suggests that if continua running from low to high levels of each characteristic are put into an inverse relationship with each other so that the highest point on the continuum for comfort with uncertainty coincide with the lowest point on the continuum for the need for peer support, the characteristics for members of each of the five adopter categories match their position on the combined continua. Thus, innovators possess the highest level of comfort with uncertainty and the lowest need for peer support. Laggards, at the opposite end of the scale, possess the lowest comfort level with uncertainty and the highest need for peer support.

One additional dimension of time related to the adoption of innovation that Rogers (1995) discusses is the rate at which the adoption of an innovation occurs within a population. He suggests that a plot of the number of adopters in a population, over time, appears as a bell curve skewed to the left. The number of adopters increases rapidly at the beginning of the adoption phase where innovators, early adopters, and early majority adopters embrace the innovation, but tapers off more slowly as the late majority and laggards incorporate the innovation and the adoption phase is completed (Rogers).

The Features of Social Structure Influencing Adoption of Innovation

The social system identified as the fourth element in Rogers' (1995) definition of the diffusion of innovation represents the boundary within which the innovation diffuses. He provides a special description of a social system as a "set of interrelated units that are engaged in joint problem solving to accomplish a common goal" (Rogers, p. 23). The significance of social structure to Rogers' model is that it provides both the regularity and stability important for predicting the behavior of its members. Information in such a structure serves the purpose of reducing uncertainty (Rogers).

A feature of the formal social structure is the communication structure within it. The communication structure may have both formal and informal elements. One property of the communication structure is that patterns of communication emerge, usually based on membership in homophilous groups. Knowledge of what groups in which an individual belongs also helps predict when that individual will adopt an innovation. This is possible because the social system's norms establish behavior patterns that define the range of tolerable behavior and behavior expectations for these groups (Rogers, 1995).

Another social phenomenon affecting the diffusion of innovation is the presence of opinion leaders or change agents (Rogers, 1995). Innovators themselves often have low credibility in the social structure and, thus, have only a limited role in the diffusion of their innovations. Opinion leaders, however, particularly informal leaders, are recognized for their technical competency, social accessibility, and conformance to norms. When they adopt innovative behavior, they model the behavior for followers but still exemplify and express the social structure. Opinion leaders usually receive more exposure to communications from outside their homophilic group, enjoy higher social status, and tend to be more innovative than the norm for their group. They often occupy the center nodes of interpersonal communication networks and act as links between the networks of diverse groups (Rogers). While opinion leaders are effective in fostering innovation within their groups, they can lose their effectiveness if they stray too far from the norms of that group or if they are viewed by their group as introducing too much change too rapidly (Rogers).

Change agents, unlike opinion leaders, are usually heterophilic. They overtly influence the direction of innovation as the representatives of formal or informal change agencies within a social structure. They exert their influence in diffusion campaigns through opinion leaders serving as homophilic aides (Rogers, 1995).

The social structure involved in innovation diffusion also plays a role in determining the type of implementation decisions that must be made in the diffusion process. Adoption of innovation may be optional and left to individual choice. It may be collective and derived from a consensus among the members of a system. Authority decisions are a third type of implementation path that takes place when small groups possessing power, status, and technical expertise make the choice to adopt or not adopt an innovation for all members of a systems. Another solution is contingent-type decisions in which choices about an innovation’s implementation are made after adoption has already begun. New external factors or initial experiences may require a reexamination of the adoption decision and alteration of the implementation plans or even their abandonment (Rogers, 1995).

Evaluating the Consequences of Innovation

Rogers (1995) suggests that it is important to evaluate the consequences of innovation and proposes three dimensions to that evaluation. First, one characterizes the effects of the adoption as either functional or dysfunctional and makes a judgment about whether the effect is desirable or not. Another dimension of the evaluation characterizes the consequences of the innovation as either direct or indirect. A third and final dimension to the evaluation is a categorization of the consequent effects of adoption as either anticipated or unanticipated. Unintended consequences often provide valuable information about relationships and dynamics among elements within a social structure (Rogers).

The Pragmatic Dimension

There are a host of factors external to a reusable learning object-based instructional system that exerts influence on its development. Not all of these factors can be addressed with satisfaction strictly within the scope of the psychological, pedagogical, technological, or cultural dimensions. Some influences on such an instructional system's development are simply matters of practicality, expediency, or necessity. In fact, some of these pragmatic influences provide the impetus for moving forward at this time with the implementation of such systems.

The Tension Between Market Demand and Institutional Accountability

The number of institutions adopting distributed learning models is increasing every year in response to market demand and increased focus on accountability in the training and educational fields (Farrington & Yoshida, 2000). The leadership of institutions successfully adopting distributed learning models focuses resources on complete degree or certificate programs that fill specific requirements or needs from their constituents (Farrington, 1999).

Web-based delivery models are attractive to institutions seeking to improve their market penetration because of their reach and their relatively cost-effective distribution models (Hawkins, 1999). Frequently, however, the demand for the production of Web-based instructional programs is greater than the resources the institution is prepared to devote to them, particularly if doing so threatens successful existing conventional programs (Hawkins).

Bothun (1999) also notes that the introduction of new technologies for the delivery of instruction has been accompanied by a corresponding pressure from the public, from academe, and from legislative bodies for leaders of learning institutions to be accountable for the quality and relevance of what they produce through these means. Conversely, market forces in today's competitive environment produce very real pressure on institutions engaged in delivering instruction with the aid of technology to trade quality for efficiency in the interest of establishing themselves as a significant presence in the market (Bothun). The production rate problem for a program is compounded by the unique demands of Web-based instruction, particularly if developers conscientiously apply theory-grounded instructional design (Hannafin et al., 1997).

Furthermore, Katz (1999) notes that there is an increasing competition afoot for students' time and allegiance brought about by the convergence of information-based technologies. The result of this competition is an increasing fragmentation of comprehensive academic institutions, similar to the market segmentation experienced by the broadcast industries as the result of cable and satellite saturation, and also similar to the narrowly focused segmentation of the magazine publishing industry (Katz). Katz suggests that an institution can only be successful in this environment if it develops the ability to differentiate among the many market niches, assesses their sizes and dimensions of growth, and focuses their intellectual resources, rather than drain them by trying to cover everything (Katz).

Change in focus within the institution adopting new instructional models also affects the members of the institution engaged in the use of the new technologies. Colbert et al. (1990) address this effect along four dimensions: (a) acceptability, (b) usability, (c) functionality, and (d) utility. The dimension of acceptability measures the degree to which the method conforms to the affective requirements of the end-user group. Usability addresses the question of whether or not the method can actually be used: the users possess the requisite skills, experience, and physical abilities to apply the tool in the execution of the task. Functionality is an expression of the degree to which the tool improves the execution of the task it is designed to support. Finally, utility is the measure of how effective the method is in aiding execution of the task the tool is designed to support.

Additionally, Colbert et al. (1990) suggest that an organization must realistically examine the cost of implementing the programs. They propose that organizations must measure any gains in productivity compared with the cost of performing the same task without the program or tool (Colbert et al.).

Organizational Context as an Influence on the Development Process

According to Colbert et al. (1999), the organizational context also plays a role in the successful planning for change brought about by the implementation of a new technology. The context within the organization in which a program is developed is characterized by elements such as the prior experience of the developers, the attitude of the users toward training, the degree of importance that confidentiality plays in professional development opportunities within the organization, and the consequences of any changes in user performance brought about by adoption of the method (Colbert et al.).

Wilson et al. (1993) note a paradox raised by the advancement of technology into the workplace. While the adoption of technology has increased the demand for highly developed skills and specialized knowledge, the automation of basic tasks and lower level work has eliminated entry-level positions that previously enabled apprentices to develop the more specialized knowledge and advanced skills over time under the supervision of a more skilled and experienced worker (Wilson et al.). The elimination of lower paid apprentice-level workers is not usually offset by the increased efficiency of more skilled workers, and it also introduces unforeseen expenses in employee turnover. Skilled technology workers are in high demand and consequently more mobile than skilled laborers of the past. The absence of a pool of apprentices from which to immediately move workers into newly vacated skilled-labor positions introduces further expense in lost productivity both because no one is performing the work while the position is being filled, and because the new worker must still be introduced to the system and workflow of the organization. This process affects not only the productivity of the new worker, but also the productivity of those who are responsible for training them (Wilson et al.).

CHAPTER III

METHOD

Introduction

The specific methodology employed in this study to explore the research questions at the heart of the inquiry is presented in this chapter. The purpose of the study was to determine how theoretical concepts underlying integrated learning object-based instructional systems translate into effective practice.

The rationale for choosing a qualitative mode of study (and the choice of a case study design in particular to frame the inquiry) is addressed in this chapter. Furthermore, illuminated in this chapter I have the context of the case under examination and described elements of the setting that had significance to the inquiry. Also addressed in the chapter are the materials and instrumentation used to produce the data for analysis. Finally outlined are the dimensions of analysis through which the collected data are processed and the role of the researcher in this process.

Objectives of Qualitative Research

Merriam (1998) proposes that one perspective on qualitative research reflects the position of the researcher as an examiner of ongoing processes. The interpretation of the data collected from such an examination constitutes the researcher’s contribution to the body of knowledge on the topic. The researcher presents such an interpretation to facilitate an understanding of the meaning that participants in the process under examination have constructed to make sense of their interaction with it (Merriam). Where quantitative research usually attempts to focus on the relationships among a small group of factors in isolation, Creswell (1998) suggests that qualitative research attempts to examine a broad range of influences in detail to both identify the thematic elements that bind them together and to describe the relationships among those influences to account for the character of those thematic elements.

Case Study Design

The single case study is one facet of qualitative research used to examine in detail a single specific instance of a phenomenon to capture, describe, and analyze its thematic essence. An examination of the development and implementation of QuickScience™, an integrated learning object-based instructional system, is a candidate for such an approach. The development of learning object databases, expert systems, and instructional design tools each have relatively well established practices and processes as described in the review of the literature in this study. The integration of elements from each of these fields into a single integrated learning object instructional system, however, is sufficiently unique to warrant examination of the process in detail as a single case. The benefit of this approach is the possibility of extracting critical thematic elements from the case through the apparatus of established theoretical constructs such as Hannafin and Land's (1997) grounded instructional design theory and Rogers' (1995) model for the diffusion of innovation. Doing so gives coherent form to the confluence of these diverse methodologies and establishes the groundwork for a new model for the design and development of learning tools. Tools developed in this fashion may help meet the evolving learning demands engendered by contemporary culture's embrace of technology. Figure 3 illustrates the relationships among the elements of the conceptual framework for the investigation.

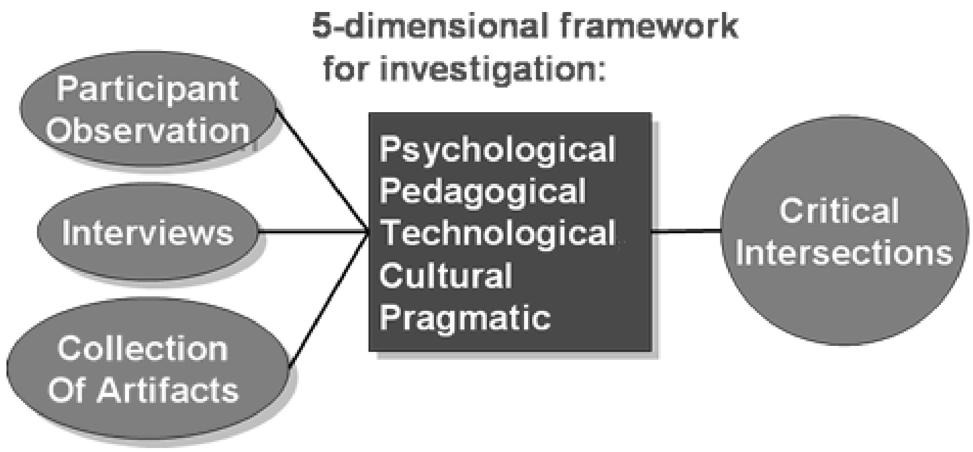

Figure 3. The five-dimensional framework for the investigation.

The Case Context

The project that is the subject of the study encompasses the development and implementation of a Web-based tool for teachers in Grades 3 through 8 to facilitate science learning aligned with national and state of Florida science standards. The tool's importance stems from the high stakes testing such as the Florida Comprehensive Achievement Test (FCAT) through which schools are being held accountable for student performance. While schools may target the gaps between actual and desired student performance on standardized tests as the areas of focus for the coming school year, teachers are often tasked with the responsibility for determining on their own how to meet the performance goals. This includes the discovery of appropriate resources, instructional material, and assessment instruments. Furthermore, despite the increased demand placed on teachers to apply technology in order to leverage classroom performance, opportunities for professional development regarding new teaching strategies and performance-improving techniques are growing scarce, especially during the school day. The development of a tool known as QuickScience™ to address these conditions is funded through a federal grant for the purpose of enhancing the resources at the disposal of teachers whose students are to be tested through the Florida Comprehensive Achievement Test for the first time in the area of science in the 2002/2003 school year.

Participants

The participants in this study include the members of the design team involved in the production of an integrated learning object-based instructional system. The design team, as a whole, serves as the unit of analysis for the study. Key team members are classified according to their role in the development and execution of the project and interviewed for their personal insight into the project's development. It is, however, the collective work representing the interactions among the entire group that accounts for the character of the project's expression of underlying theoretical principles. The project team includes full-time university faculty members and technology support staff, doctoral students, a contractor programming specialist, and local school teachers contracted to manage and coordinate production and development tasks. Team members of interest to the study include the (a) project director, (b) tool design coordinator, (c) curriculum coordinator, (d) instructional designer, (e) content production coordinator, and (f) programming designer.

The project director serves as the coprincipal investigator for the federal grant and provides the conceptual foundation and oversight for the project. The project director also serves as the project's principal public spokesperson.

The tool design coordinator links the theoretical concepts behind the functionality of the tool to the technological means for their expression. Such a position serves as a bridge between the philosophical foundation driving the reasons or requirements for the tool and its manifestation through a coordinated assemblage of technologies.

The curriculum coordinator documents, aligns, and cross-references the informational content, instructional strategies, practice items, and assessment items that constitute the learning objects in QuickScience™ with the array of state and national science standards driving the requirement for the tool. The curriculum coordinator also develops an instructional scope and sequence for the resources as a performance support feature of QuickScience™. Another task performed by the curriculum coordinator is to ensure that the content of each learning object is appropriate for the objectives of the standard and employs developmentally appropriate reading levels.

The primary instructional designer determines the most appropriate instructional strategy, sequence of information, type of supporting materials, and assessment method that constitute each learning object type. These are then aligned to meet the requirements for each science standard addressed in the tool.

The content production coordinator ensures that all of the content elements required by the instructional design for each learning object are identified and scheduled for production. The elements are also checked for conformance to the design specification and appropriately described for retrieval with metadata tagging.

The programming designer instantiates the tool's design through the development of computer language code. The programming designer applies the languages and technologies necessary to perform the functions expressed through the conceptual framework. Additionally, the programming designer ensures that the application's development conforms to accepted practices and industry standards for interoperability and transportability to make the tool flexible, extensible, and scalable.

The Setting

The University of West Florida serves as the host institution for the federal grant supporting the project, the development team, and the QuickScience™ technical infrastructure. Within the university's College of Professional Studies, the Center for Innovative Technology provides the administrative home for the QuickScience™ project as well as the physical setting for most of its development and implementation activities.

With the exception of the instructional designer and content production coordinator, none of the project team members are engaged in the project on a full-time basis. Their work on the QuickScience™ project is a task they undertake in addition to their full-time responsibilities, including administration, teaching, and other university and community service projects.

The university supports the project and has undertaken steps to commercialize it for national distribution. Likewise, the dean of the college in which the project is based strongly supports the project. The area's school districts permit individual schools to serve as test sites for prototypes of the tool with the endorsement of the districts' curriculum coordinators.

Most work on the project is conducted individually or in fluid collections of team members gathering to resolve specific points in the development process. The resolution of these points is usually then disseminated electronically via e-mail and supporting attachments to the group as a whole. Larger, less frequent meetings of the project team are held to address important conceptual issues and to coordinate group effort in response to urgent deadlines or work plan modifications.

The Content: The QuickScience™ Integrated Learning Object Instructional System

The QuickScience™ tool provides for the enhancement of science learning through two primary avenues. The tool provides science learning content that is aligned with both the national science standards and the Florida Sunshine State Science Standards. Additionally, the tool offers support for the teacher of science by providing access to the tool's learning content through a continuum of mediation. At its most basic level, the mediation includes a completely prepared curriculum reflecting a ready-to-consume scope and sequence for the entire school year. The opposite end of the continuum involves the most advanced mediation. This includes the creation of an instructional Web site for each teacher through which individual resources are collected, modified, and presented to learners through a teacher-customized scope and sequence. Individual performances as well as class performance as a group in the standards-aligned assessments are tracked and reported to the teacher for analysis.

An additional feature of QuickScience™ is the degree to which it incorporates performance support for the teacher. The performance support is intended to minimize the need for specialized training for the teacher in order to incorporate the tool into the instructional process. This is to be accomplished as quickly as possible and with a range of integration into the curriculum that is not dependent on the teacher's instructional design and development skills.

The technical development of the QuickScience™ tool reflects incorporation of the Cisco model for reusable learning objects outlined by Barritt and Lewis (2001). The reusable learning objects themselves incorporate the Sharable Content Object Repository Metadata (SCORM) standard for descriptive metadata. Additionally, the objects are implemented through a Microsoft SQL Server database and delivered and managed through Microsoft Active Server Page technology. This approach is adopted to enable the greatest flexibility in application and scalability in implementation possible for the tool. In summary, QuickScience™ is a tool that employs reusable learning object technology to provide standards-aligned Web-based science learning content. QuickScience™ reflects a range of learning and teaching strategies, as well as an array of selection, development, and management tools for classroom teachers to exploit in the delivery of that content.

Procedures

Three protocols served as data collection instruments. Each protocol was reviewed and approved by The University of West Florida's Institutional Review Board for Human Subjects (Appendix A).

Evaluation of the integrated learning object-based instructional system was conducted by the researcher through a screen-by-screen inspection of the main application functions related to the selection, evaluation, organization, and delivery of learning object resources. A protocol was used to identify and record the properties of features reflecting underlying psychological, pedagogical, technical, cultural, and pragmatic foundations (see Appendix B). Particularly important elements such as the user interfaces for searching, managing resources, and analyzing learner performance, as well as general performance support elements, were graphically captured as exhibits for later reference.

Concept papers, design documents, reports, and e-mail correspondence were examined with a separate, similar protocol to identify and characterize explicit references to underlying psychological, pedagogical, technical, cultural, and pragmatic foundations (see Appendix C). The researcher had direct access to all documents regarding the project either because (a) the researcher already possessed the original electronic document, (b) was coauthor of many documents and so was aware of their existence, or (c) was in daily contact with team members who had other known documents or were willing to permit a search of their file storage area for any others. Copies of the documents and the notes recorded in the protocol form served as data for analysis.

A third protocol for conducting individual interpersonal interviews was used (see Appendix D). The researcher met individually with each subject in a setting of the subject's choosing. The researcher stressed to each subject that candor in their responses to the questions was very important and that care would be taken to ensure that their identities were protected. Questions asked by the researcher were designed to elicit responses that addressed psychological, pedagogical, technical, cultural, and pragmatic issues related to the development of the tool. Each interview was audio taped and a written transcript was produced. The resulting transcripts were examined with the documents protocol.

Data Collection Methods

The three protocols were employed to aid in the collection of data from each of three classes of sources. The protocols are all based upon Hannafin and Land's (1997) five dimensions of grounded instructional design: (a) psychological, (b) pedagogical, (c) technological, (d) cultural, and (e) pragmatic.

Collection of Artifacts

Materials used for this study included the integrated instructional system itself. The tool is called QuickScience™. It was examined in accordance with an evaluation protocol, included in Appendix B, to identify features that reflect the five dimensions of grounded instructional design: (a) psychological, (b) pedagogical, (c) technological, (d) cultural, and (e) pragmatic. Additional materials included concept proposal documents, design documents, project reports, and other documents that surfaced to help characterize the theoretical underpinnings of the project.

Unstructured Interviews

Fifteen main interview questions grouped along the five grounded dimensions (psychological, pedagogical, technological, cultural, and pragmatic) served as the basis for the collection of data from interviews with the principal QuickScience™ team members (see Appendix D). Each question, usually accompanied by two or three follow-up questions, was focused on one of the five grounded dimensions, but was sufficiently open-ended to engender detailed discussion about the thought processes the subject engaged in while pursuing completion of the project. Information about the subjects' educational and professional backgrounds was also collected to draw the character of their responses into greater relief.

Transcripts of subject interviews and any e-mail correspondence related to requests for clarification or amplification of responses served as material for analysis. Copies of the electronic versions of these transcripts enabled the researcher to sort, search, and organize the raw data for analysis.

Data Analysis Procedures

The data analyzed for the study came from examination of the integrated learning object-based instructional system itself, examination of the collected documents, and from transcripts of the personal interviews and correspondence with selected members of the QuickScience™ project team. This data were supported by additional observations and recollections of the researcher in the role of participant observer. The protocols for collection of the three types of data were designed to reflect the five dimensions of grounded instructional design theory that serve as the framework for analysis of the data collected.

The analysis of the collected data included initial grouping of data elements along the five dimensions of Hannafin et al.'s (1997) grounded learning systems design theory. These dimensions provide the initial framework for organizing the data as illustrated in Figure 4.

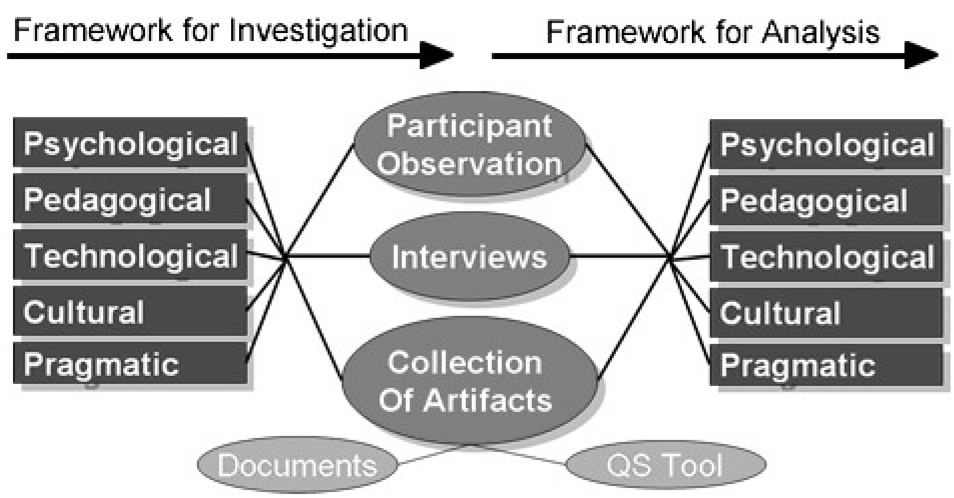

Figure 4. Relationship of investigation and analysis frameworks to data.

By associating data from the collection protocols with base-line concepts derived from the literature, important relationships or thematic affinities among the responses and the theoretical framework may emerge. Themes developed through a pattern-matching process served to refine the emergent constructs into coherent patterns aligning the practices and products represented by the case with the underlying theoretical framework (Creswell, 1998).

The principal research question for the study was as follows: How do theoretical concepts underlying integrated learning object-based instructional systems translate into effective practice? Five subquestions served as the foundation for initial organization:

1. What psychological concepts are important to integrated learning object-based instructional systems, and how are they reflected in practice?
2. What pedagogical concepts are important to integrated learning object-based instructional systems, and how are they reflected in practice?
3. What technological concepts are important to integrated learning object-based instructional systems, and how are they reflected in practice?
4. What cultural concepts are important to integrated learning object-based instructional systems, and how are they reflected in practice?
5. What pragmatic issues are important to integrated learning object-based instructional systems, and how are they reflected in practice?

Verifying Qualitative Data

Recognizing the significance of data is often dependent on collecting enough data to allow patterns to emerge (Stake, 1995). The interviews with the six key members of the QuickScience™ development team should produce a sufficient amount of data. Additionally, the distinct roles played in the development process by each member should aid in the identification of and lend significance to common thematic elements that emerge from the data. The triangulation afforded by the diversity of the individual team members was compounded by the introduction of data derived from the protocols examining the tool itself, as well as the diversity of design documents, electronic communications, white papers, and presentation materials addressing the purpose, properties, and functionality of the tool. It was the responsibility of the researcher to accurately identify, collect, and report the data as objectively as possible and to be as candid as possible about the influences driving the selection and analysis of particular data. Figure 5 illustrates how triangulated data support the confirmability and verification of the materials examined through the five dimensions of the study's framework.

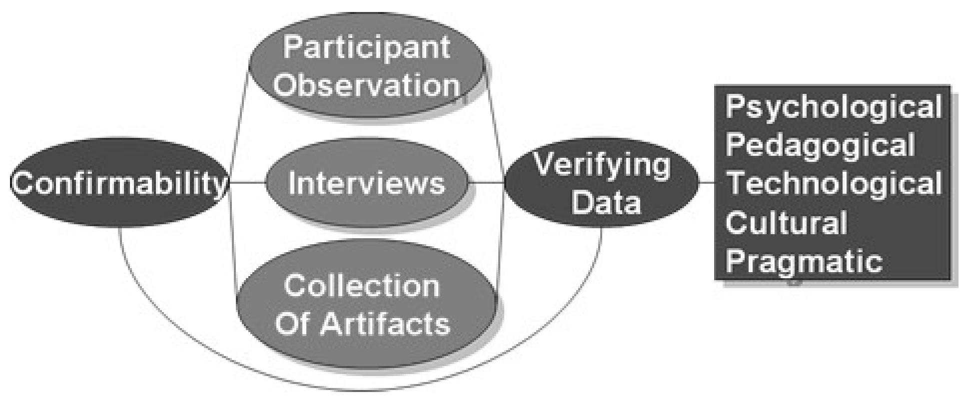

Figure 5. Confirmability and verification supported by triangulated data for analysis.

The Role of the Researcher

While Merriam (1998) and Creswell (1998) both suggest that the researcher in qualitative studies may occupy any place along a continuum of interaction or involvement with the subject of the study and its participants, they stress that it is critical that this relationship is openly addressed in detail as a part of the study. The researcher in this study assumed the role of participant observer and, as Stake (1995) proposes, was in a position to both observe the phenomenon under study from an internal perspective and to interact with the members of the design team at the heart of the study with a richness that may be less likely for an outside observer.

The participant observer engaged in the study of the QuickScience™ integrated learning object instructional system served as the interviewer for each of the members of the project team that were subjects of the study. While the list of research questions asked of each team member were uniform, the participant observer researcher had historical knowledge of the team's development efforts that may aid in probing issues that surface during the subjects' responses to interview questions. Additionally, the participant observer researcher was aware of the existence and location of a very broad range of documents associated with the project that may not be considered significant enough to mention to an outside researcher by the project team members, but may be the source of additional important insight into the nature of the project's development.

Perhaps the greatest value of a participant observer researcher comes during the analysis phase of the study. Personal insight into the dynamics among project team members with respect to the execution of the project and awareness of the details of the issues addressed during the development of the tool may help crystallize information into propositions that would otherwise remain unconnected data.

Researcher Bias

Several factors associated with the researcher's role as a participant observer described in the section above also raised concern for the investigator because of the role researcher bias may play in their expression. In the case of the QuickScience™ project, the participant observer researcher served as one of the principal theoretical architects of the concept and inventor of the tool. There was potential in this instance for the researcher to see successes as confirmation of the endorsed theoretical principles while less successful elements may be explained away as the result of failure to follow, poor execution, or misinterpretation of favored concepts.

The triangulation of data from documentation, interviews, and inspection of the QuickScience™ tool itself should help ameliorate the effect of researcher bias. Furthermore, the adoption of an established grounded framework for the investigation that approaches the data from psychological, pedagogical, technological, cultural, and pragmatic perspectives aids the triangulation process. Such an approach should also produce enough discussion of the data in the analysis phase of the study for researcher biases to emerge as patterns in the treatment of the data.

Confirmability

Subjects of the study were provided the opportunity to review the information derived from their interviews. They confirmed and included corrective responses or amplifications to aid the accurate reporting of their positions. Additionally, drafts of the study were subjected to periodic review by members of the researcher's dissertation committee to guide the researcher into thinking critically, as Creswell (1998) suggests, about the meaning of the information being developed in the study.

Ethical Considerations

No attempt was made to obscure the name of the project itself or the hosting institution. The real names of the QuickScience™ project team members were not used, however, in order to preserve their anonymity. Notes from the personal interviews identified the subjects only by the role they played in the project development team. References to the interviews in the study contained only generalized information regarding the learning and cognitive theories to which they ascribe, experience with the instructional design process, and delivery of Web-based instruction. References in the study contained no explicit information that could be used to determine the exact identity of any of the subjects or any other personal information other than that they were members of a design team at their respective organizations engaged in the development of learning object-based instructional design tools. References by name to participating subjects in all documents collected from the project directors were obscured.

CHAPTER IV

ANALYSIS OF DATA

Introduction

The purpose of this study was to determine how theoretical concepts underlying integrated learning object-based instructional systems translate into effective practice. The theoretical model employed for this investigation is Hannafin et al.'s (1997) grounded instructional design model. They require in that model that a successful implementation of an instructional system must address the five dimensions of the design model: (a) psychological, (b) pedagogical, (c) technological, (d) cultural, and (e) pragmatic. A number of the most critical issues from the literature associated with each dimension serve as the framework for the investigation and are explored from three approaches.

First, an examination of the design documents and white papers that serve as the theoretical foundation of the QuickScience™ instructional system provides documentary evidence for links to the conceptual issues in the framework. The second approach is composed from interpretations of the transcripts of personal interviews that the investigator had with six of the key design team members of the QuickScience™ project. Finally, a third approach is through a critical analysis of five of the main screens of the

QuickScience™ tool itself for evidence that the screens reflect a position on the conceptual issues in the framework.

The Data Sources

There are three sources of data addressing each of the five dimensions of the investigation. These include (a) a collection of observations by the investigator of the seminal documents that serve as the theoretical foundation of the QuickScience™ instructional system, (b) a collection of interpretations of the personal interviews with the QuickScience™ design team conducted by the investigator, and (c) a critical analysis of five of the main QuickScience™ user interface screens.

The Documents

All five of the theoretical documents that constitute the foundation of the QuickScience™ instructional system concept are authored by various combinations of three of the project design team members. These include the (a) project director, (b) curriculum coordinator, and (c) tool design coordinator.

The first document, entitled *Resource Builder* (Dawson, 2002), is a paper developed very early in the project. It was intended for internal dissemination to the design team and served as supporting material for a briefing delivered by the design team to Ms. Gloria Gery, the electronic performance support expert, who critiqued the conceptual development of the tool up to that point.

A document entitled *QuickScience™: A Research View* (Northrup, Rasmussen, & Dawson, 2002b) is one from the QuickScience™ White Paper Series. This series was produced to document the theoretical underpinnings of various features of the QuickScience™ instructional system for the benefit of the company conducting market analysis for introduction of the tool as a commercial product.

Another document from the White Paper Series is *Using the Cisco Model* (Northrup, Rasmussen, & Dawson, 2002a). The document outlines the unique implementation of the Cisco reusable learning object model employed by the QuickScience™ instructional system.

A third document from the White Paper Series is *QuickScience™: A Performance-Centered System* (Northrup, 2002). It identifies and traces the origin of the underlying premises that shape the performance-centered orientation of the development team's approach to software tool development.

The final document, *Designing and Reusing Learning Objects to Streamline Web-Based Instructional Development* (Northrup, Rasmussen, & Dawson, in press), is a book chapter prepared by the project director, curriculum coordinator, and tool design coordinator to be published in 2004. The document addresses the general principles and the theoretical origins of the concept of designing instruction with reusable learning objects.

The Interviews

The investigator conducted personal interviews with the six principal design team members of the project. These included the project director, the curriculum coordinator, the project manager, the content coordinator, the programming coordinator, and the tool design coordinator. All of the interviews except one took place in the investigator's office at The University of West Florida. The content coordinator’s interview took place in her office at Pensacola Junior College. Each interview was between 90 minutes and 2 hours in duration and followed the interview protocol. The protocol itself permitted slight variations in the direction of the interview based on the subject’s responses, and the interviewer took the initiative to pursue particularly interesting avenues of inquiry in more detail if they emerged during the interview. An audiocassette recording of each interview was made. Each audiocassette was converted into a digital Windows Media File and transcribed into an electronic text transcript by the interviewer. The subjects all signed informed consent forms and had the opportunity to review a copy of the electronic transcript in order to make any corrections or to provide clarification if desired (Appendix E). No one opted to make any modifications to his or her transcripts.

The one exception to this procedure was in the case of the tool design coordinator. Since he is also the investigator in this study, he simply typed his responses to the interview protocol questions directly into a text file. Every effort was made to make this interview as conversational in tone but as deep in scope as the interviews with the other team members.

The QuickScience™ Interface Screen Layouts

There are five major screen layouts from the interface of the QuickScience™ instructional system that are the subject of critical analysis for this investigation. Each was chosen because of the degree to which major features and functions of the tool intersect at these points. All of these screen layouts are from the Release Version One of the QuickScience™ instructional system.

The first screen, the Main Page, is the entry point to the tool from the World Wide Web. It is the first screen in the tool seen by all users of the tool and by all visitors to the tool.

The second interface screen subjected to critical analysis is called This Week. This screen serves two main purposes. It is the entry point for student access to a curricular program that changes each week throughout the year according to a published scope and sequence. It is also the point in the site richest in information describing the resources contained in it and performance support elements for learning how to use them.

A third interface screen is the My QuickScience™ location. This screen is only accessible to users who have established an account in the tool. It is a place rich in tools for searching, previewing, selecting, and managing resources for the teacher’s own class Web site.

The fourth interface screen is a portion of the interface that is common to most of the screens in the tool. It represents some of the ubiquitous performance support elements embedded in the QuickScience™ tool and includes the avatar support character, Flo, that represents the availability of certain types of support

The fifth interface screen examined is the Communicator. This screen serves as the learner interface to the instructional resources contained in the tool and, as such, functions in a much different way from the rest of the screens addressed in the study.

Method for Reporting and Analyzing Data

Modification of Research Protocols

The research questions, as they are framed in the document review protocol and the design tool review protocol, proved unsatisfactory to the researcher for gathering meaningful information from the three types of data sources. The solution involved an evolution and simplification in form of the questions back to the original five subquestions as they are expressed in chapter 1 and chapter 3.

One motivation for modifying the questions had to do with the dynamics of the personal interviews. The original questions did not provide enough information to the subject to stimulate recall or prompt conversational elaboration to the depth required for an exhaustive exploration of the topics. They also did not reflect the natural divisions of the subject matter as they began to emerge from the interviews. An alternate protocol for interviewing subjects was developed and submitted to The University of West Florida's Institutional Review Board for approval and implemented (Appendix F).

A second issue with an original research protocol addressed the same problem for the researcher as with the interviews, but from the perspective of the analysis of the documents and screen captures of the QuickScience™ tool itself. The research subquestions included each of the five dimensions of the investigation: (a) psychological, (b) pedagogical, (c) technological, (d) cultural, and (e) pragmatic. Each of the five original subquestions in the document and screen analysis protocols were divided into narrower subquestions seeking explicit and implicit evidence of expressions of the main concept in the interface or in the support elements of the tool. These divisions proved too artificial and often too redundant for meaningful exploration. A more direct approach to both the document and screen capture analyses was adopted by reverting to the original research questions supported by the additional subject prompts found in the personal interview protocol. These modifications also provided the best alignment of the data among all three protocols for more powerful analyses of the research questions.

Data Coding

The software application nVivo, version 2.0 by QSR Pty. Ltd,. was used to code the text-based document, interview transcripts, and interface screen critical analyses. A separate grouping, or node, for each of the five dimensions included subnodes for each related topic. Within the topic nodes, three additional subnodes were created for the documents, interview transcripts, and interface screen critical analyses. The texts were reviewed by the investigator and assigned to the corresponding nodes in portions varying in size from a single sentence to a complete paragraph. Some text elements were assigned to more than one node. A negligible portion of the text received no node assignments. The text assembled around these nodes served as the basis for analysis for the topics associated with those nodes.

Reporting Format

The reporting and analysis of the data follows the outline of the five dimensions of the investigation, which correspond with the five research subquestions of the study. A separate section is presented for the psychological, pedagogical, technological, cultural, and pragmatic dimensions and the related research subquestion. Each of the subquestions is supported by a number of related topics. These topics emerge from the literature as particularly significant issues in their corresponding dimension and are deliberately addressed in the study because of their critical nature. An exploration of the topics related to the research subquestion developed from the review of the design documents sets the foundation. This is followed by a similar synthesis of the corresponding subsection and related topics in the five interviews and concludes by an examination of the thematic issues related to the subquestion and corresponding topics as they emerge from the critical analysis of the interface screens in the QuickScience™ tool itself. The analyses are conducted to identify common themes related to the subquestion and related topics within each data type, and a summary for each dimension is provided to explore thematic pattern across all three data types.

The Data

The principal research question for the study is: How do theoretical concepts underlying integrated learning object-based instructional systems translate into effective practice? Five subquestions serve as the foundation for initial organization:

1. What psychological concepts are important to integrated learning object-based instructional systems, and how are they reflected in practice?
2. What pedagogical concepts are important to integrated learning object-based instructional systems, and how are they reflected in practice?
3. What technological concepts are important to integrated learning object-based instructional systems, and how are they reflected in practice?
4. What cultural concepts are important to integrated learning object-based instructional systems, and how are they reflected in practice?

5. What pragmatic issues are important to integrated learning object-based instructional systems, and how are they reflected in practice?

Each of the five subquestions is addressed through a number of topics derived from the literature specific to the dimension under examination. These topics serve to focus the inquiry and give form to the exploration of the fundamental issues related to the subquestions.

Project Goals for QuickScience™

It is important to document an examination of the record of the stated goals of the QuickScience™ project in advance of an analysis of the theoretical underpinnings of the tool. Such an examination is important because it sets a context that characterizes all of the collected data.

The White Paper Series document, *QuickScience™:A Research View*, provides the stated purpose for the project that contains elements common to all of the documents:

> QuickScience™ is a Web-based performance support tool designed to assist teachers in planning, implementing, and evaluating student performance in science. The curriculum resources within QuickScience™ are aligned to standards and provide multiple types of assessments for classroom practice.
>
> QuickScience™ is a flexible online solution for implementing standards-based science in the classroom. (Northrup et al., 2002b, p. 1)

Each document reflects a slight shift in focus toward the specific concepts being addressed in a given document. The notions of performance support for teachers implementing standards-based science instruction in the classroom, however, are voiced with emphasis that is consistent across all the examined documents.

Psychological Dimension

What psychological concepts are important to integrated learning object-based instructional systems, and how are they reflected in practice?

Within the psychological dimension, four topics emerged as particularly important to integrated learning object-based instructional systems. These included the information acquisition process, knowledge representation, knowledge organization and individual differences, and context.

Information Acquisition

Information acquisition in the documents. Interestingly, for a project so deeply focused on performance support, there are no references in any of the documents selected for analysis that directly relate to the psychological processes of gaining attention and information acquisition. The reason for this may simply be that the documents selected address the project at too high a level to include discussion at this level of detail in this area.

Information acquisition in the interviews. The interviews regarding the topic of information acquisition reveal a rather sharp distinction between members of the design team most closely and most recently associated with classroom teaching in public elementary or middle schools, and members with little or no such experience. A division also exists between team members directly engaged in the production of the tool’s instructional resources and those more closely involved in the design of the tool's interface. The teacher/production group expressed their thoughts on information acquisition in terms best summarized by the content coordinator's statement that "The WOW factor is always a great way to get them to want to learn more," or "they want to learn something because it looks like it's fun to learn." The project manager also suggests that the user interface for the learners "had to be more cartoonish, with bright colors."

The interface designer group addressed the issue with references to the information processing model and the physiology of cognition. The tool design coordinator provided a detailed explanation of memory management in the brain's sensory registers and described two features critical to the design of the tool:

> First, although researchers believe that the brain allocates separate memory space to sensory registers of varying sizes to each of the senses, the sensory register for visual information often borrows space from the verbal information registry, and information from both places are acted upon by control processes. The efficiency of the data transfer from sensory register to short-term memory is dependent upon the control processes activated at the time. This means that the individual must be in a compatible "frame of mind" in order for information to even be recognized as significant. Second, information being transferred from short-term memory to long-term memory makes the trip most accurately and completely when the information elicits a response from the learner. The implication is that there is an optimal type and degree of interactivity that improves the retention of certain types of information.

Information acquisition in the interface screen analysis. To the layman's eye, the essence of the screen designs in the QuickScience™ tools reflects a concern for drawing attention to specific areas in the screen consistently for specific kinds of information and for eliciting engagement with the interface as a means for guiding the user through the processes associated with each screen. The screens display rich landscapes representing natural science attractions and use font size, color, and style to convey special information. There is also evidence of a deeper, more deliberate application of scientifically based design principles in the development of the interface as this excerpt from the analysis of the Main Screen illustrates:

> The layout of the screen elements follows an eye-scanning pattern commonly used as the basis for graphic design principles that first traces a diagonal line from bottom right, where bold text exhorts the viewer to "Begin Now!" to top left, where the tool's logo is displayed. Next, the eyes scan across the top of the screen from left to right, ending where the important support and navigation features represented by universally recognized icons are displayed. Finally, the viewer scans back to the top center where a very brief slogan describing the purpose of the tool is placed, for a slower, less focused scan down the entire screen including four support buttons arranged in an arc across the center of the screen. These four support buttons represent the viewer's own questions about the nature of what is being viewed, but they represent very different approaches to getting that information. This variation accommodates individual differences in support requirements for users of the tool. The downward scan of the screen also passes over a photorealistic image of children collaborating on some type of science-

related activity. The image conveys the social context of the learning environment being promoted by the tool and the discovery-based orientation of the content. Finally, the downward scan ends on the words: Get Science Quick!, a succinct, direct appeal to the viewers to take action in an area for which they know they are to be held accountable and with the speed that promises to aid them in meeting all of the demands placed upon them in the classroom.

Summary for information acquisition. While the foundation documents do not address the topic directly, the evidence in the interviews and the interface screens suggest that principles of information acquisition are considered important and are of concern to the designers. There also appears to be consensus among the designers as to the application of those principles throughout the tool, though they are articulated differently in terms that reflect the vocabulary of the speaker's trade.

Knowledge Representation

Knowledge representation in the documents. The issue of knowledge representation is generally addressed in the foundation documents in terms of describing a classification system for information that divides it into cognitive levels based upon a hybrid of Bloom and Krathwohl's taxonomy and Merrill's component display theory (Northrup et al., in press). The essence of the concept is that information represented in the tool's reusable information objects (RIO) is either of a type that must be remembered or used, and if it is to be used, there are sublevels of comprehension, application, analysis, synthesis, or evaluation. The cognitive level of the information drives the method of presentation and instructional strategy for the RIO.

Knowledge representation in the interviews. The interviews reveal disparity in theoretical engagement in the project, at least in terms of its expression, between the part of the team involved with the production of the instructional resources and the part of the team involved with the design of the interface. The essence of the production-oriented members' positions on knowledge representation is that learners must build upon foundations of knowledge already in their possession and that simulations are a means for permitting learners to put things together the way they think things work. The notion of foundational knowledge implies a cognitive organization with familiar structures upon which new knowledge is fixed because the new knowledge is represented in the context of the existing knowledge. It simply is not robustly expressed. The notion of simulations implies a constructivist approach that permits learners to derive, through trial and error, representations of knowledge consistent with their mental models. Again, the concept is simply not expressed in that way in conversation by the interview subject.

The notion of knowledge representation is more robustly addressed by the members of the team most involved with interface design, but not without complications. The boundary for some between knowledge representation and knowledge organization is tenuous. This is particularly true in the case of the curriculum coordinator and programming coordinator. Such an orientation is understandable given that both roles require a great deal of focus on the organization of resources in the tool. Rather than characterize this as an error in perception, however, it is perhaps more useful to view knowledge organization as an extension of the notion of knowledge representation. Schema, or mental models, place knowledge in structures. The relative positions of these nodes of information play a vital role in their usability for cognitive function; thus, organization may in some ways be viewed as an interdependent property of the representation of that knowledge.

The curriculum coordinator also provides valuable insight into the character of the structure of the information in the QuickScience™ tool. She describes the evolution of the structural model for the QuickScience™ Web lesson from a very early predecessor of the tool, the Lesson Architect, an instructional planning tool part of a larger teacher planning and performance tool, STEPS. This information had become obscured by the design team's focus on the Cisco model for reusable learning objects (RLOs).

Another important theme emerges from the interviews: the notion, that as the project director states, "It is difficult to develop an environment that accommodates all representational models." The best solution, in the case of the QuickScience™ tool, is the adoption of familiar metaphor. This proved especially successful in the area of the search engine for the tool. The value of the metaphor is described by the tool design coordinator, who suggests that people prefer to store information as stories. He proposes that people (a) use common elements and common relationships among elements for which they have a preference to compose stories or (b) assign incoming information to common story elements for which each individual has preferences. He illustrates the power of this notion by noting the popularity of assigning new lyrics to popular tunes, or how readily we are able to apply the same metaphor to the explanation of many different things.

Knowledge representation in the interface screen analysis. A conceptual thread running commonly through the interface screens is the importance placed on the activation of preexisting schema in the user to facilitate the user's grasp of and access to important features of the tool. In many cases it is simply the use of graphical elements to establish a set of expectations as with the learner's content interface screen, the Communicator.

The Communicator screen contains a representation of some type of futuristic electronic communication device. The screen's strangeness serves the purpose of gaining attention but also serves the purpose of establishing an expectation on the part of the user of interaction with the screen because it is both labeled as a communicator and its appearance is consistent with other communication devices to which the learner is likely to have been exposed.

In other cases, certain schema or mental models are activated in the user by text laden with clusters of associated expectations as in the example excerpted from the Main Screen analysis:

> The terms *This Week*, *Portal,* and the prefix "*My_*" added to another term have become universally recognized conventions in Web-based applications to denote sets of features clustered together to support a particular kind of activity. The term This Week implies a cluster of resources or activities focused on a particular topic. The term Portal has become a general Web convention for a common area through which any user may initiate a search of the contents of the site and possibly of other sites as well. Again, searching activities involves the use of metadata to refine and focus the searches. The conventions commonly associated with the use of the prefix My__ on a Web site include the expectation that some degree of user-enabled customization, or control over the nature, quantity, and appearance of the site's contents, is possible.

Summary for knowledge representation. There is consistency in the evidence across all three data sources in the desirability of drawing on the user's preexisting knowledge and knowledge relationships to facilitate the assimilation of new information presented through the QuickScience™ tool's interface. Also, the foundation documents as well as the interviews reflect a strong inclination on the part of the design team to extend the concept of knowledge representation to include the relational aspects of the organizational structure of knowledge. The implication is that much is to be learned about knowledge elements by recognizing their place in a greater knowledge structure.

Knowledge Organization and Individual Differences

Knowledge organization and individual differences in the documents. The foundation documents do not contain any specific references to underlying psychological concepts regarding knowledge organization and individual differences. These areas are, however, addressed from the pedagogical perspective and are discussed in the corresponding section of the data analysis.

Knowledge organization and individual differences in the interviews. Two notions stand out from the interviews regarding knowledge organization and individual differences. The first notion is that while the range of individual experiences is broad among people, the character of knowledge elements and the manner in which knowledge elements are related and organized in cognitive structures are essentially generic in character. The inference gained from this notion is that a relatively small number of common but different strategies address the great majority of users. These strategies serve to both convey information to teachers about how to use the tool, like scaffolding, and to learners to convey the instructional content, like cooperative learning experiences in heterogeneous groups address the great majority of users.

The second notion is that people have preferences for certain combinations of these generic cognitive tasks. The comments of the tool design coordinator elaborate on this:

> Although a group of individuals may have a vastly divergent range of experiences, the arrangement of those experiences into a structure for knowledge operations is probably composed of very common elements. These consist of content and associated relational information clustered around intersecting points of knowledge that function as reference points that serve as sort of higher order maps to the knowledge contained in the structure. Again, we probably have favorite or preferred focal points though which we frequently enter memory to retrieve whatever we need at the moment. Things in closer approximation to these favored key nodes, especially to multiple ones, tend to get remembered more easily and are acted upon by mental tasks with less effort. Information that is in close approximation to other less favored major nodes is the next most easily recovered information; the fewer node connections, the harder to retrieve. Finally, the information least closely associated with the least number of least favored nodes is the least likely to be recovered and may even eventually be extinguished unless some activity draws upon that cluster of information in time.

A successful tool will demonstrate the ability to express its specialized functions through generic task structures in order to reduce the cognitive load on the user of the tool. The content coordinator observed that there are times when the designer must simply provide the common experiences first to serve as the foundation from which new knowledge is built.

Knowledge organization and individual differences in the interface screens. The interface screens in the QuickScience™ tool make use of common computer interface conventions wherever possible to provide users of the interface with visual cues for which predictable expectations and associated behaviors are attached. Access to support elements are usually presented through text links that are usually phrased in question form to provide the individual more robust characterizations of the kind of support associated with the link. These support features vary in strategy and approach. Users may select the kind of support element that best suits their individual preferences in knowledge organization. These characterizations may also help to frame vague uncertainties the user may be feeling about the tool into the context of more familiar, well-defined terms.

All of these features across the interface screens examined represent an effort to provide a familiar feel to the operation of the tool. At the same time, the tool provides for multiple approaches to resolving needs for support when they emerge.

Summary for knowledge organization and individual differences. The variety of knowledge organization in the cognitive structures across individuals, and individual preferences or habits for knowledge operations within those structures, present less of a problem for designers of instruction than they may appear to do. The framing of new knowledge within the context of existing generic tasks and the use of metaphor to represent their relationships permit enough commonality among individuals for effective learning of the new knowledge and its integration into the learner's existing knowledge structure.

Context

Context in the documents. The foundation documents reveal no references to the psychological aspect of the concept of context as it relates to the QuickScience™ tool. There are references to the classroom environment and to collaborative learning strategies, but they are from the perspective of pedagogy.

Context in the interviews. A notion that is universally noted by the design team is the importance of a graduated spectrum of learning contexts. At one end, there is a need for individualized experiences for the acquisition of certain kinds of knowledge. At the opposite end is a collaborative environment rich in features to help the learner fix information into a knowledge structure. The programming coordinator provides a strong case for attention to context throughout the spectrum by linking context to relevance as a component of learning motivation and performance support.

The design team expressed satisfaction with the development of two new RLOs, the Web Quest, and the Science Experiment because of the degree of social context inherent in their instructional design. The individualized character of the Web lessons left most of the design team unsatisfied and they expressed general relief when the new RLOs were introduced. Notably, the most experienced elementary school teachers on the team expressed a general preference for the earliest version of the tool which was composed of a series of integrated simulations to maximize situated cognition.

The tool design coordinator provides a theoretical foundation for the importance of context:

> The concept of social learning is consistent with the notion that critical nodes of knowledge are accessed through numerous pathways that establish relationships among numerous bits of information. Where a person is, who they are with, what a place or person smells like, the color of the sunlight, the taste of the gingersnap cookie may all pass through the same point in a person's cognitive structure, but from different directions. The more pathways to a node, the more likely information associated with the node may be recalled by a knowledge operation. Also, knowledge associated with an event involving elicited performance tends to have stronger recall potential, so interactions with others, which are simply series of performance elicitations, qualify as particularly effective in building the recall power of knowledge nodes associated with them. While there may be preferred pathways through cognitive structure, it is the whole structure, including the weak or obscure connections, that build its value to its user. Well-structured problem spaces provide good rehearsal events to expand the range of preferred knowledge pathways within the context of the learning environment. They reduce the "noise" that distracts the learners from rehearsal and reinforcement of the target operation. This noise is what they would probably encounter in attempting to solve the more common, ill-structured problems in their normal environment, but the mental habit must have an opportunity to develop and become robust before it can accommodate refinement. It is important to build skill in solving problems by first

addressing the operations with few variables and then gradually introduce more variables as performance improves.

Context in the interface screens. The essence of context as it is expressed through the examined interface screens is that consistent placement and function of interface components are important. These components provide a work space for the users that permits the users to focus on the new tasks presented on a screen without having to relearn functions with which they already have experience.

Another notion that emerges from an examination of the interface screens is a focus on social learning experiences. The evidence supporting this concept is that the major interface screen designs include photographic images of children working together. It is an especially dominant image on the Main Screen, which has the principal purpose of conveying the nature of the tool to newcomers.

Summary for context. The theme that emerges from the data sources is that context is a powerful aid to the construction of knowledge in a tool such as QuickScience™ because it establishes a framework around which information can be placed. Context may range from individualized experiences through collaborative exercises, depending on the kinds of information being presented, but in all cases should support the relevance of the information to sustain the motivation to learn.

Summary for the Psychological Dimension

A pattern that develops from an examination of the dominant themes from each of the topic areas in the psychological dimension is a trend in the QuickScience™ project for the team members not to consciously focus discussions on psychology-related theoretical foundations. Expressions of certain theoretical concepts are indirectly in evidence in the manifestation of the tool and are apparent as undercurrents to the interviews, but very little direct and explicit reference to these concepts is found.

Another pattern inferred from the evidence is that the design team embraces the notion of generic task structure and metaphor. They employ these generic tasks and metaphors as means of packaging specialized knowledge into forms for which users already have mental models and schema that can be readily activated. Their intent, which is universally expressed, is to exploit generic task structures to reduce the cognitive load on the user to make the tool easy and desirable to use.

Finally, an emphasis on knowledge organization is apparent in all three sources of data. This emphasis is driven to some degree by the nature of the content that the tool supports and the origin of the reason for the tool–mandated state testing against standards. The focus in this area may also reflect the nature of the underlying technology making the tool possible, namely, database-driven dynamically populated content.

Pedagogical Dimension

What pedagogical concepts are important to integrated learning object-based instructional systems, and how are they reflected in practice?

There are several pedagogical topics of particular interest for designers of learning object-based instructional systems. Three that emerged as especially significant from the literature include the constructivist orientation in a learning systems environment, knowledge objects as instructional design components, and instructional strategies.

Constructivist Orientation

Constructivist orientation in the documents. The foundation documents place a great deal of emphasis on the ability of the user to participate in a range of QuickScience™ activities, all with the focus of providing standards-aligned science instructions to learners, but with three very different approaches. Flexibility is a keyword in the characterization of the tool in the documents.

Constructivist orientation in the interviews. The dominant theme from the interviews regarding where people placed themselves between a cognitive and constructivist orientation is that this is not a fixed position. The universal response is that factors such as the learner, the learning outcomes, the goals, and other noninstructional issues drive the orientation of the project. The consensus is that constructivism is a heuristic subject to eclectic expediency.

The project team members do make a point of noting that the tool reflects a range of approaches to instruction from the almost behaviorist character of the Web lessons (which originate in the Cisco model for RLOs) to the heterogenous group collaborative learning-oriented Web Quests and Science Experiments. These two RLOs are the result of development efforts by the design team in response to dissatisfaction with the cognitive model that limits the Web lesson derived from the Cisco model. The ability to select from this range of instructional resource types, of course, reflects a constructivist approach to the tool itself as reflected in the project director's comment:

> What we are suggesting is that you build a very solid knowledge base before you ask the learner to apply and extend that knowledge. Through the five different sets of resources that we have, we're progressing from building to applying. The

science experiments and Web quests are where we see the application of knowledge. Also, those five areas start from a very individualistic perspective and progress to a more collaborative environment, so they are learning on their own at first and then learning together.

There is also great concern among the team members that the tool easily accommodates a broad range of work processes followed by teachers using the tool: (a) the ability to access the search tool from multiple locations, (b) the options to manage their own site, (c) to ability to perform diagnostic tests, or (d) the ability to choose between assessing or not assessing their learners from within the tool. These processes are available to the user but are not requirements for successful use of the tool.

Constructivist orientation in the interface screens. The interface screens provide the users with a wide range of options at almost every point but support those options with visual cues and text prompts that characterize what the users are likely to find or be able to do should they follow the link. The critical thing is that no decision elicited from the user working in the tool is unsupported. A heuristic tone is evident in the presentation of information and choices, but there is seldom a point where the user can only choose a single path or disengage.

Summary for constructivist orientation. The data reflect two main themes regarding a constructivist orientation in the QuickScience™ tool. The first theme is that constructivism is a relative term for a heuristic that is subject to modification among the circumstances of its application. In fact, the curriculum coordinator best illustrated this by suggesting that constructivism is simply a form of cognitivism that extends the locus of control over the learning experience out to the learner. The second theme is that the main concept underlying constructivism is that it is desirable to provide choice and alternatives, but with a purpose to support performance, not simply for the sake of choice itself.

Knowledge Objects as Instructional Design Components

Knowledge objects as instructional design components in the documents. The main theme from the examination of the foundation documents is that the instructional design process, as it is conducted in a system based upon a Learning Object repository, such as QuickScience™, differs little in concept from traditional methods. The documents suggest that what differences do exist are essentially improvements, such as greater simplicity and improved effectiveness. Simplicity is cited by most of the documents as stemming from the fact that the design process for the user is narrowed down to problems of selection and sequencing resources. Improved effectiveness is reported as a benefit because the bulk of the instructional design work is embedded in the structure of the learning objects themselves, thus reducing variability in execution of design (Northrup, 2002).

Knowledge objects as instructional design components in the interviews. One thing that becomes apparent from the interviews of the project design team members is that there is quite a difference in attitude toward learning objects as instructional design components between the members of the team involved with production of the objects and members of the design team involved with design of the interface. The production group finds learning objects to be both restrictive in form and unfriendly to the creative designer. The interface design group, on the other hand, views learning objects as emancipating for designers because so much of the design work is embedded in the form of the object. They also draw attention to the efficiencies in production this represents and the flexibility in application the use of such objects provide the designer.

Part of this difference is explained by the fact that most of the production team had left the project before the development of the new object types, the Web Quest and Science Experiment, and were, thus, justified to some degree in their perception of the limitations of the concept. Other comments revealed, however, a deeper dissatisfaction with the separation of the content from the presentation elements. The production team members have strong visual arts backgrounds, and part of their satisfaction in producing instruction is enjoyment of the creation of the visual design of their work. They express dissatisfaction at being denied satisfaction in the learning object development process.

The interface design team embraces the flexibility offered by the variety of learning object types and the corresponding variety in instructional strategies and approaches. They tend to express relief from having to perform what they characterize as the drudgework of design.

From the perspective of how flexibility affects the work processes of the user of the tool, however, there is greater consensus. Most team members mention favorably the benefits to the teachers in being able to select and sequence objects in their own class Web sites according to their needs without having to produce the materials.

Knowledge objects as instructional design components in the interface screens. The concept of learning objects is not overtly addressed in any of the user interface screens. However, they are manifested when the user manipulates learning object properties when selecting Web lesson components.

The compound design of the screens dynamically populated with learning objects is completely transparent to the user by intent of the design team. The screens appear as single, static pages. The focus for the user is instead upon the direct and simple execution of the tasks that are made possible by the underlying and wholly invisible technology.

Summary for knowledge objects as instructional design components. The flexibility, efficiency, and consistency offered by adoption of a learning object instructional design model is a dominant theme in the data record. Satisfaction with the model as a work process appears to depend on one's proximity to the actual creation of the object. This suggests that the problem is not so much the concept, but the design of the interface tool for the creation of the content. A more imaginative production interface with more stimulating GUI (Graphical User Interface) properties may resolve this issue.

Instructional Strategies

Instructional strategies in the documents. A common notion among the documents regarding the nature of learning objects is that the instructional strategies for the content are embedded in the form of the learning object, and each learning object type employs a different instructional strategy. The documents note that while the Cisco model for learning objects provides for the application of different instructional strategies based on the type of content to be delivered, the choice in strategy is up to the designer (Northrup et al., 2002a). The QuickScience™ model simplifies the choice process for the developer of the objects because the instructional strategy is embedded into the form of the object itself. The developer simply has to choose the type of object she wishes to use. The user of the tool itself also has only to choose from an array of object types associated with a particular standard in order to select the most appropriate instructional strategy for the user's purposes.

Instructional strategies in the interviews. An interesting theme that develops from interviews with the QuickScience™ design team is that the embedding of the instructional strategies into the learning object types was not a goal that the team had in the beginning of the project. It developed instead through serendipitous fortune. The team recounts their dissatisfaction with the limitations of the original learning object model derived from the Cisco model, mainly because of what they perceived to be the limited opportunity in this format to accommodate different learning styles. As the team struggled through the process of defining the properties and organizational structure for the new learning object types from the perspective of their technological implementation, a match emerged between the format of the object and the instructional strategy it employed. Once this connection was apparent, the development process for the new types proceeds without difficulty and a particularly difficult instructional design issue was resolved at the same time.

Instructional strategies in the interface screens. The instructional content resources themselves represent the manifestation of their related instructional strategies. These strategies are reinforced through the teacher-related support elements that identify the inquiry-based components of the tool and are evident in the descriptions of the resources that appear as the result in the search tool.

Summary for instructional strategies. There are two themes from the data that stand out regarding instructional strategies. The first theme is that multiple instructional strategies are important in a constructivist-oriented tool such as this, and there should be resources that employ more than one strategy type for any topic. The second theme is that the instructional strategies employed in the QuickScience™ tool are embedded in the learning object type. To select a different instructional strategy for a particular topic, the user simply has to choose the object type that best fits the desired outcome.

Summary for the Pedagogical Dimension

Important themes emerge from the data sources regarding issues in the pedagogical dimension. One notion is that constructivism is probably best described as a relative term for a heuristic that is subject to modification among the circumstances of its application.

The flexibility, efficiency, and consistency offered by adoption of a learning object instructional design model is also a dominant theme, but satisfaction with the learning object instructional design model as a work process appears to depend on one's proximity to the actual creation of the object. Additionally, it is important for a constructivist-oriented tool, such as QuickScience™, to incorporate multiple instructional strategies for any topic. Perhaps the most significant idea regarding the pedagogical dimension as it relates to the QuickScience™ instructional system is that its instructional strategies are embedded in the learning object type.

Technological Dimension

What technological concepts are important to integrated learning object-based instructional systems, and how are they reflected in practice?

The technological dimension is addressed through four topics that are of importance to learning object-based instructional systems. Performance support is a dominant theme at the center of such systems. Knowledge operations in technology-based tools, metadata, and development methodology also constitute important issues that designers' successful systems must address.

Performance Support

Performance support in the documents. Ease of use for the teacher emerges as the dominant theme from the data sources regarding performance support in QuickScience™. The document record, in fact, seems to be much more concerned with addressing the teacher performance support features of the tool than with anything else, including the instructional content.

The performance support approaches as described in the documents follow two themes. The first is the implementation of task structures that are efficient and, more importantly, similar in form to processes with which the teacher is already familiar, such as plan, teach, assess, or search, select, and show. The second is the form and variety of support elements that consistently appear at the points where a teacher may need support that hints at the approach and depth of that support in the character of the prompt.

The QuickScience™ White Paper, *A Research View*, provides a succinct summary of the tool's support elements:

> QuickScience™ is designed using the attributes and behaviors of performance-centered systems with a strong focus on usability. QuickScience™ has many intrinsic features that support the teacher while using the tool. "Check with Flo" is

> a major feature providing coaching to the teacher on how to use QuickScience™ serving as a bridge between the Web-based tool and the realities of day-to-day life in the classroom. Other guidance includes a series of questions available on each screen that provides “How do I use this” and “Show me an example” scaffolding to encourage “day-one performance” for the teacher. QuickScience™ also automates many tasks including creating a custom Web page for teachers with all of the resources that are gathered through a simple and advanced search. (Northrup et al., 2002b, p. 1)

Performance support in the interviews. An interesting division in the development team between those who are themselves willing users of performance supports and help features in software, and those who are not, emerges from the interviews. The most experienced elementary school teachers strongly express their opinions that a teacher, alone in the classroom, will not use elaborate performance support. Their position is that the tool requires in-person, on-site professional development training and local support for teachers in order for the teachers to be willing to adopt it. The opposing camp in the development team holds the position that the intrinsic and overt supports are so integrated in the work processes of using the tool that to use it is to learn it. They cite the successful pilot implementations in a local school district as support for their position.

The major theme regarding performance support from the interviews is that the goal of performance support as it is manifested in QuickScience™ is to make the job of teaching easier for the expert and novice alike. Also this goal should be accomplished without significantly altering the task structure of the job. The curriculum coordinator expresses this notion in the following way:

> To me, the fundamental task of performance support is to make tasks easier so that people who are busy, or who do not know what they are doing, can perform their tasks easier, better, [and] more accurately and increase whatever performance aspect of their job is supported. I think QuickScience™ meets those requirements, plus the elements of help and scaffolding, and the way that teachers' work processes are shadowed by the technological structure of the tool help make it so that teachers don't have to relearn a task structure to use the tool which they would not do. We have spent a great deal of effort through a number of iterations of the tool modeling that task structure to make sure we are not imposing another, foreign task structure on someone working in the classroom.

Another major theme from the interviews is that in order for performance support to be successful, the developers must have intimate knowledge of the work processes under review. The developer must use that knowledge to distill the performance issue down to its most basic unit. The project director quotes Gloria Gery in describing the goal of this process as "naming that tune in one note."

Performance support in the interface screens. Analysis of the interface screens reveals two common performance support features consistently in evidence. One feature is the placement of the performance support at the point of performance where it is most needed and most accessible. The column of Flo Facts presents to the user a collection of questions immediately adjacent to the task on the screen. This example also reflects the second feature, which is that the language of the support link prompts actually initiates the problem resolution process by framing the performance problem before the user selects its link.

An additional characteristic of the performance support dimension of the tool is the implementation of intrinsic support. The use of common task structures, like search engines, or common navigational icons to support the work processes in the tool reflects intrinsic support. The support lies in the user's familiarity with the task metaphor and associated behavior expectations.

Summary for performance support. The focus of effort in the area of performance support as represented in the source data is on making the supported task easier to perform, making performance of the task more efficient, and improving the quality of performance of the task. An essential feature of performance support as it is implemented in the QuickScience™ tool is that the best performance support is the support that is transparent to the user because it reflects grounding in familiar, generic tasks and metaphors.

Knowledge Operations in Technology-Based Tools

Knowledge operations in technology-based tools in the documents. Documentary evidence addressing knowledge operations in technology-based systems is limited to three areas. First, most documents contain statements about the flexibility in application of RLOs in constructing customized bodies of knowledge in QuickScience™. Second, while not overtly stated in such terms, the documents infer the expression of the heuristic model for QuickScience™ through the avatar character Flo and its associated performance support elements. Finally, the documents characterize a framework for the nature of the practical world embodied by the tool and the solutions it provides for successfully negotiating the demands of this environment.

Knowledge operations in technology-based tools in the interviews. A common thread running through the interviews is concern for making certain that the tool conveys an ontological basis for how the goals of its tasks fit into the world of the classroom learning environment. The curriculum coordinator provides a comprehensive characterization of the world in which the tool is intended to operate:

> The pragmatic view was that students are going to have to pass tests that reflect the standards. The material we create and the knowledge to which we are mapping them has already been outlined and organized. Whether it's into strands or benchmarks, we need to map to that same structure because the reality is that the learners will be tested on those specific areas. So in the creation of the materials, we went back to standards, which set the structure for what kinds of skills learners should have, what kinds of knowledge they ought to acquire, and what the realities ought to be.

There was also agreement among team members that while some concepts are relatively easy to represent visually, others, such as relationships, methods, and goals, are more difficult and it is important to find common symbols from within the culture of the tool's environment to represent metaphorically those concepts if the tool is to improve the performance of tasks dependent on them. The developers require a deep understanding of the symbols, relationships, and hierarchies of task groups in the tool's work environment.

Knowledge operations in technology-based tools in the interface screens. The design of the examined interface screens suggests that the prominence and nature of the support elements closest to the focus of the user on the screen at any given time conveys the heuristic message that these areas should be of concern or interest to the user. The user support elements in the interface contain the message that the tool possesses a flexibility of design that easily tolerates experimentation and change. What is not expressed to the user, by conscious action of the designers, is that this functionality is made possible through the tool's foundation upon learning object technology.

Summary for knowledge operations in technology-based tools. The knowledge operation embodied by the QuickScience™ tool makes use of familiar symbols to express relationships, methods, and processes imbued with a heuristic sense of what ought to be, and within the context of the tool and through these expressions, describes its place in the task environment of the user. The performance support elements of the tool provide the control knowledge and metaknowledge required by the user to successfully apply the tool within a standards-based accountability environment.

Metadata

Metadata in the documents. The foundation documents reviewed for this study do not address the importance of metadata to the functionality of the QuickScience™ tool. The main reason for this is that its importance to the tool did not become prominent for most of the development team until after the creation of most of the documents, when access to an expert programmer in the person of the programming coordinator became available. Its critical function is, however, evident in the interviews and screen analyses.

Metadata in the interviews. Although the project team members involved in the interface design universally affirm the critical role metadata plays in the functionality of the QuickScience™ tool, there is also dissatisfaction with the narrowness of its standardized implementation. Since the metadata proves so valuable in the manipulation of the resources for development purposes, the team expresses a desire for the expansion of the standards-compliant metadata taxonomy and a more robust and descriptive vocabulary for metadata to expand its flexibility. The members of the team engaged in the design of the interface have extended the domain of active metadata users beyond the technical programming functions, where it is an established feature, to include the interface designers themselves and extensions to the metadata taxonomy in order to extend the functionality of the tool. Their desire is to see a further extension of the functionality of standardized metadata to include support for processes that make such metadata accessible to the end user.

Members of the production element of the team do not express as intense an affinity for the metadata in the tool. They had become disengaged from the project before it began to figure prominently in the refinement of the tool.

Metadata in the interface screens. The search tool interface and the search results make use of metadata manipulation to filter and select resources based upon descriptive information about those resources. The evaluation of search results, their selection, and their display status for the learner also involve access to certain metadata components. These elements play a key role in the functionality of the tool. Many of the support elements make use of metadata about the nature of the underlying support at the point of performance in the tool’s interface.

Summary for metadata. Metadata plays a critical role in the functionality of the QuickScience™ tool. It also figures to play a very large part in the expansion of the functionality and ultimate evolution of the tool in subsequent revisions. The scope and robustness of the standardized implementation of metadata has not kept pace with the expanding requirements for it. Much of the character of the role metadata will play in the evolution of the tool will be determined by the development team's ability to adapt the metadata concept to its purposes.

Development Methodology

Development methodology in the documents. The only references to development methodology in the foundation documents examined are in the very early "Resource Builder" (Dawson, 2002) document, an internal reference document developed to support a very early prototype review by the electronic performance support expert, Gloria Gery. The document does identify the O'Keefe and Lee (as cited in Adelman & Riedel, 1997) development spiral as the model for the QuickScience™ design team's development methodology. It describes an iterative and evolutionary process that repeats a sequence of steps in cycles that terminate each time in the following succession: (a) a theoretical model, (b) a prototype, (c) a pilot model, and finally, (d) a full production implementation. It also mentions the Brown Electronic Performance Support System (EPSS) define, design, develop, and deliver model as the basis for developing the project's requirements analyses (as cited in Dawson, 2002).

Development methodology in the interviews. The interviews regarding development methodologies provide the sharpest divisions in thinking of all the interview topics among the project members. The two key members of the project team directly involved in the production of the resources and responsible for directing and managing the production efforts of the content development contract staff convey strong levels of discomfort with the development process. There are two main sources identified by these team members for this discomfort, but both originate from the same event.

The first source, mainly expressed by the project manager, is that the project was never really fully planned out and, as a result, there were so many changes in direction and focus that the production team responded by reverting to a kind of mechanical execution of their tasks because they neither fully understood nor particularly liked what the changes meant to them and to their work requirements. In the project manager's opinion, this resulted in a poorer quality output than they had envisioned at the beginning of the project.

The second source of discomfort, mainly expressed by the content coordinator, is that when the project changed directions away from the initial integrated multimedia learning application toward the adoption of the RLO concept, the production of content turned into, as she puts it, "pure drudgery." The dullness of the development process coupled with the increased number of resources was a source of pronounced disappointment to her. She also reported that the contract production staff quickly fell into to a disengaged, mechanical work pattern, and she reported that since she felt personally responsible for the quality of the materials being produced, she assumed the role of editing the content herself, a role she found particularly distasteful.

The rest of the development team, those involved in the design of the user interfaces and the underlying database and in programming the functionality of the tool, expressed not only a high degree of comfort with an iterative approach to tool development, but a genuine preference for it. This is best expressed by the tool design coordinator:

> Rapid prototyping as a development process in a collaborative environment offers several benefits. Use of the method permits the developers access to the features and functions of the tool within the context of all of its elements. The natures of the relationships among the various components of the tool are not always apparent when considered in the abstract and the actual properties of real-time task behavior are very difficult to assess any other way. In fact, developers using rapid prototyping may more easily establish the sequencing and flow of task structures because they are able to model those tasks earlier in the development cycle. Also, multiple sets of eyes looking at the same tool as a whole from different perspectives contribute to the accuracy of the representation of the tasks as well as the sequencing and hierarchical relationships among them and enables developers to make corrections and modify their parts of the project before too much time and effort is spent on developmental dead ends.

The interface design team members categorically reject a common argument that proposes iterative design is design by repair. Their response is that this fluidity in design permits greater flexibility and nimbleness in refining the tool for a particular application. They suggest that such nimbleness has become a critical feature in the design process as the rate of change in design requirements increases in response to accelerated business cycles.

Development methodology in the interface screens. There are no manifestations of iterative design methodology apparent in the interface screens examined, other than the implication in the support elements that the tool permits such an approach to the development of instruction by the teacher through the use of the My QuickScience™ site resource management interface.

Summary for development methodology. The iterative rapid prototyping design model for tool development is an approach not easily tolerated by developers ascribing to the comprehensiveness of the traditional instructional design model. It may also be that such an approach is simply more tolerable when the scope of the work involved in making major design changes is not overwhelmingly huge. The capability to be flexible in the design process is becoming an increasingly important fact of life for developers of RLO-based tools, but it is probably dependent on the proper design of the underlying data structures.

Summary for Technological Dimension

Performance-centered design serves as the foundation of the tools teachers and others will need as requirements and expectations change while requirements for accountability grow. An important function of such tools is the conveyance of heuristic approaches to work processes from within the ontological context of the job environment.

Metadata, databases, and rapid prototype design permit immense flexibility and responsiveness to change in the development process for performance support applications. However, flexibility and responsiveness seem to come at the cost of satisfaction and loss of emotional investment in the work process for those most directly affected by such changes.

Cultural Dimension

What cultural concepts are important to integrated learning object-based instructional systems, and how are they reflected in practice?

Two topics characterize the exploration of the cultural dimension of the study. The revolt against traditional instructional design and the implications for designers of learning object-based instructional systems is one topic. The other topic, which is a logical extension, or end piece of the first topic, is the nature of the diffusion of innovation.

Revolt Against Traditional Instructional Design

Revolt against traditional instructional design in the documents. The QuickScience™ White Paper series document, Reusable Learning Objects, is the only foundation document that directly addresses the issue of inadequacy in the traditional instructional design methodology for meeting the demands of today’s learning and support environments. The premise of the document is that the redundancy and wasted effort associated with repeatedly applying such a process anew to each instance of instructional demand must stop and that the adoption of an approach to instructional design that incorporates the concept of RLOs offers a desirable alternative.

Revolt against traditional instructional design in the interviews. The common theme that emerges from the discussions with the QuickScience™ project team members is that the validity of the rejection of the traditional instructional design model depends upon the granularity of the thing being designed. Certainly, instructional systems benefit from an alternative approach such as RLO technology (so must the design of RLOs themselves) but the traditional model becomes more attractive and seems a better fit when the granularity approaches the level of single concepts.

A more satisfying approach to dealing with the problems associated with the traditional instructional design model, that it is (a) too slow, (b) independent of the content being designed, (c) of questionable efficacy, and (d) promotes an erroneous world view, emerges from comments by the design team. They suggest that the traditional instructional design model was never intended to be a formulaic ritual, but that it should rather be internalized heuristics, acculturated gut feelings that stimulate thought in certain directions, but do not compel the designer to follow those feelings when other factors suggest alternate paths.

Revolt against traditional instructional design in the interface screens. The user interface screens do not address the issue of conflict between traditional instructional design and alternative approaches. The screens do, however, manifest an alternative instructional design approach in the My QuickScience™ section.

Summary for revolt against traditional instructional design. The essential theme from the data sources on problems with traditional instructional design brings to mind the Aristotlean admonition to embrace all things in moderation, none to excess. Slavish adherence to any instructional methodology seems to be rejected by members of the project team with varying levels of conviction.

A reasonable replacement for the traditional method of instructional design is the form of RLO technology which provides a better fit for modern design requirements with the cautionary note that it also has flaws that can be overcome through the application of rational intellect.

Diffusion of Innovation

Diffusion of innovation in the documents. The foundation documents reflect a focus mainly on the notion that the QuickScience™ instructional system confers a significant advantage to adopters of the tool. The documents suggest that those who follow more traditional approaches to implementing standards-based science education in their classroom will not benefit from the efficiency of the process, the simplicity of the methods, or the validity of the approach embodied in the QuickScience™ tool.

Diffusion of innovation in the interviews. It seems that the relative advantage of the QuickScience™ tool to teachers is a foregone conclusion to the project team and is often dismissed with little elaboration. Most team members express greater concern that the tool proves compatible with the teacher's existing work processes and is easier to use than other possible solutions to the challenge of implementing standards-based science education in the teacher's classroom.

The tool design coordinator's comments summarize this frame of mind in the team members:

> The tool itself, by its own definition, points to the relative advantage it offers the teacher over more conventional methods of teaching science: resources aligned and sorted by standards, focus on tested standards, and, perhaps most importantly, an integrated planning, presentation, and assessment environment. It provides support elements that relate the activities in the tool directly to familiar teaching practices. The ability to undo change, and modify selections and their presentations, provides a very strong trialability quotient. The Web-based format

means that many interested parties may observe the work and results of the teacher's efforts–administrators, parents and peers.

The team generally expresses confidence that the tool will prove successful, particularly in light of the success of the pilot implementation through a local school district.

An interesting subtheme emerges in discussions about the implementation of the RLO model in the tool. There is concern that the design team did not do enough work in meeting the requirements for successful diffusion of this innovation throughout the development team itself.

Diffusion of innovation in the interface screens. The user interface screens reflect a high degree of concern with the elements of successful diffusion of the tool. The user-support elements emphasize the relative advantage of the tool over other methods. The use of familiar terms and processes in the tool confirms its compatibility with the teacher's environment. The primary focus of the design of the tool is the reduction in complexity of the instructional development process. The flexibility of the tool, particularly in the My QuickScience™ interface, encourages the users to try out any number of permutations of their class site. Observability is somewhat problematic because the sites are password protected.

Summary for diffusion of innovation. The elements of the diffusion of innovation seem to form an undercurrent to the project team's efforts and often emerge in fragments of conversation or as expressions of the properties of features in the tool within the tool's own support elements. There does not appear to be, however, undue concern with documenting the comprehensive treatment of each element.

Summary for the Cultural Dimension

The revolt against instructional design and the conditions for the successful diffusion of innovation seem to fit together in a natural sequence. If the designer has truly rejected the security of the traditional instructional design process for another methodology, the elements of diffusion may serve as a reality check for the validity of the output of whatever process or combination of processes the designer has embraced. Ultimately, the elegance of a design or attractiveness of a technological solution are meaningless if the tool has little chance of adoption.

Pragmatic Dimension

What pragmatic concepts are important to integrated learning object-based instructional systems, and how are they reflected in practice?

The pragmatic dimension contains factors that are usually unique to a particular project, but are essentially fall into two categories. Issues usually emerge in the form of organizational pressures that shape the tasks featured in the system or in the form of production pressures that are manifested in the features and functionality of the tool being produced.

The Pragmatic Dimension in the Documents

The competency of Florida learners in the area of science is soon to be assessed. The assessment will be measured against statewide standards. Schools and teachers will be held accountable for student performance. These factors amount to a serious challenge to the time and resource management skills of the classroom teachers who must address these factors in addition to all the other tasks required of them.

Another theme running through the document is the evaporation of support for professional development. This is occurring at the same time that the accountability bar is being raised. Finally, QuickScience™ is being presented as a solution to the challenges faced by teachers undergoing an increase in workload and responsibility without the benefit of professional development opportunities to address those increases.

The Pragmatic Dimension in the Interviews

Two areas of focus regarding pragmatic issues developed from the interviews with QuickScience™ project team members. The first theme follows the line of thinking reflected in the documentary evidence in addressing the market forces supporting the development and adoption of tools like QuickScience™. These forces are characterized as the advent of teacher accountability for the pending assessment of standards-driven science education and the concurrent evaporation of support for training, professional development, and education in general. The project team members consistently point to the efficiency, effectiveness, simplicity, and flexibility of the QuickScience™ tool as a solution for addressing those market forces.

The second theme unexpectedly emerged from discussions about development methodologies but addressed the pragmatic issues associated with the direction of the development of the QuickScience™ instructional system. Several team members cite a number of milestone events, for which progress or completion of certain phases of the project were expected, as crystallizing moments in the project’s development that drove adoption of certain expedient choices that may not have otherwise been implemented. The nature of the first implementation of the learning object technologies (just prior to the evaluation of an early version of the tool by the electronic performance support system expert Gloria Gery) is cited as an example of redirection of focus toward creating a usable-looking tool rather than toward a more methodical plan of action to resolve underlying technological issues in the tool's content input system. A similar occurrence involving the presentation of the tool at a scholarly conference is noted as an example of focus on the appearance of the interface at the expense of the development of a more satisfactory implementation of fundamental working parts of the tool. These issues are noted as problematic by the portion of the team most closely associated with the production of content resources, but are not reported in a negative light at all by the design team.

The Pragmatic Dimension in the Interface Screens

The pragmatic themes associated with the QuickScience™ interface screens examined closely follow the elements of successful innovation diffusion. The screens present and reinforce, through performance support elements, a practical benefit to the user in terms of an interface that is so simple to use and aligned with common work tasks that it quickly becomes transparent to the user. The user performance support elements address, in nearly every case, pragmatic issues such as effective use of the tool in a classroom with only one computer or the integration of resources from the tool's scope and sequence of weekly curricula into a district's planned curriculum.

The issues of speed and comprehensive alignment with performance standards for which the teacher is to be held accountable establish a strong pragmatic case for adoption of the tool. These may be especially persuasive factors in the adoption of the tool by novice practitioners of science education.

Summary for the Pragmatic Dimension

The essence of the evidence from the data regarding the pragmatic dimension is that there are forces external to the QuickScience™ tool that play significant roles in both the likelihood of its adoption by users and in the nature of the development of the tool itself. The response by the design team to the former often shapes the character of the latter.

Thematic Patterns Across Dimensions

General patterns emerge in an examination of the themes characterizing important aspects of the QuickScience™ instructional system from the perspective of the five dimensions of grounded instructional design. First among these is the inclination toward adoption of generic tasks and familiar metaphors to facilitate critical tasks specific to the tool and to characterize important knowledge relationships that would otherwise engender difficulties for users of the tool.

Another pattern is a general disregard for strict adherence to any knowledge model or methodology when pragmatic factors threaten progress toward the project’s goal of providing a robust standards-aligned instructional system that teachers will embrace with enthusiasm. An additional related pattern is the very high comfort level of most of the design team with rapid and often radical changes in direction and focus.

CHAPTER V

DISCUSSION

Introduction

The purpose of this study was to examine and characterize the translation of theoretical concepts underlying integrated learning object-based instructional systems into effective practice using Hannafin et al.'s (1997) grounded instructional design model as the framework for analysis. Data have been collected from sources associated with such a project, the QuickScience™ instructional system, and organized, analyzed, and reported from the perspective of the five dimensions of the design model: (a) psychological, (b) pedagogical, (c) technological, (d) cultural, and (e) pragmatic.

The purpose of this chapter is to characterize the important relationships between the concepts associated with each of the five dimensions (psychological, pedagogical, technological, cultural, and pragmatic) as they are addressed in the literature and their expression through the data collected. Additionally, both an examination of some limitations of the study as it has been conducted and a general outline for avenues of future research suggested by the outcome of the study are contained in this chapter. Finally, a summary of the most important themes revealed by the study is also contained in this chapter.

Findings

Psychological Dimension

What psychological concepts are important to integrated learning object-based instructional systems, and how are they reflected in practice?

A pattern that develops from an examination of the dominant themes from each of the topic areas in the psychological dimension is a trend in the QuickScience™ project for the team members not to consciously focus discussions on psychology-related theoretical foundations. Expressions of certain theoretical concepts are indirectly in evidence in the manifestation of the tool and are apparent as undercurrents to the interviews, but very little direct and explicit references to these concepts are found.

Cooke (1994) and Jackson (1999) acknowledge that the elicitation of knowledge, especially procedural knowledge, from experts is very difficult. They also suggest that the knowledge elicited from them is often inaccurate, particularly when elicited from them in an environment outside the context of the performance of their expertise.

One possible explanation for this difficulty suggested by this investigator, especially from the perspective of the QuickScience™ development team, is that these psychological concepts are fundamentals that have long since been built upon, elaborated, and modified by subsequent higher order operational knowledge. The locus of knowledge operations associated with the team's normal work is at higher levels in their cognitive structure. The subjects simply do not see these concepts as discrete items of knowledge from the perspective of their normally activated cognitive structures, especially if significant time has passed since these were last addressed and the links to those nodes have grown weak.

Another pattern inferred from the evidence is that the design team embraces the notion of generic task structure and metaphor. They employ these as means of packaging specialized knowledge into forms for which users already have mental models and schema that can be readily activated. Their intent, which is universally expressed, is to exploit these generic task structures to reduce the cognitive load on the user in order to make the tool easy and desirable to use.

Rumelhart and Ortony (1977), Bareiss (1989), and especially Chandrasekaran (1989) address the notion of complex cognitive structures being composed of combinations of very simple, generic tasks arranged in numerous combinations to form common schema for basic cognitive functions that are activated as they are required. The size of the activated structures or task clusters or schema varies depending on the number of familiar tasks that are associated with it.

A very good analogy is the notion of an energy conscious person entering a darkened house. As the person moves from room to room, the person activates the lighting for that room in order to make the performance of the tasks in the room easier. When the person leaves a room for an extended period, the person deactivates the lights in that part of the house to save energy, but activates the lights in the new room just entered. The person may only need a little light in a specific area, but the whole room is lighted, and so the person is enabled easily to do much more than the single purpose for which the person originally entered the room. The researcher suggests that when a task is structured so that it triggers the activation of a familiar generic task, the designer then has easy access to the entire schema structure of which it is a part, to a greater or lesser degree, in any given individual.

Finally, an emphasis on knowledge organization is apparent in all three sources of data. This emphasis is driven to some degree by the nature of the content that the tool supports, and the origin of the reason for the tool–mandated state testing against standards. The focus in this area may also reflect the nature of the underlying technology making the tool possible, namely database-driven dynamically populated content.

Merrill (2000) suggests that successful problem solving or learning is dependent not only on both the number and kinds of schema in a state of activation at the time of performance, but also on the organization of knowledge in the learner's mind. The knowledge structure theories of Ausubel (1968), Jolley (1973), and Jonassen and Henning (1999) also focus on organizational models to explain the efficiency and power of knowledge models.

The focus among the QuickScience™ design team members on knowledge organization may have found voice through the novelty of the implementation of a database-driven knowledge repository which demanded resolution of certain knowledge organization issues; however, this researcher suspects that a deeper, more compelling reason for this near preoccupation in this area is simply that once a database of flexible design is available, such as the one created by the programming and design team, the ease and simplicity of reorganizing, filtering, cross-indexing is so great that it stimulates creative thinking about the organization of data and encourages experimental modeling.

Pedagogical Dimension

What pedagogical concepts are important to integrated learning object-based instructional systems, and how are they reflected in practice?

Important themes emerge from the data sources regarding issues in the pedagogical dimension. One notion is that constructivism is probably best described as a relative term for a heuristic that is subject to modification among the circumstances of its application.

Lebow (1993) champions the notion that constructivism has been mistaken for a methodology when it is really a philosophy. Petraglia (1998) supports this, but proposes that the instructional designer can bridge the gap between theory and practice by manifesting constructivism through strategies such as collaborative learning, apprenticeship, and legitimate peripheral participation.

The researcher proposes that the literature's theorists and the project's practitioners have very different reasons for expressing similar positions. The theorists appear to be starting from the premise that constructivism is a good thing and seek to define practices that reflect its principles. The practitioners, all of whom have teaching experience (most at the elementary school level), have observed things that have worked in the classroom. They embrace the methods, but ascribe to the theory only to the point where its prescriptions are consistent with the practical management of their environment.

The flexibility, efficiency, and consistency offered by adoption of a learning object instructional design model are also dominant themes, but satisfaction with the learning object instructional design model as a work process appears to depend on one's proximity to the actual creation of the object. Those working closest to creation of the object were least satisfied with the model. Additionally, it is important for a constructivist-oriented tool such as QuickScience™ to incorporate multiple instructional strategies for any topic.

Barritt and Lewis (2001), Merrill and the ID2 Research Team (1996), Murray (1998), and Wiley (2002) extol the flexibility, efficiency, and consistency in instructional design facilitated by the adoption of learning object technology. They identify an object's property of granularity as an issue for developers because there is no agreement on the optimal level of granularity. If an object's scope is too small, management and selection become difficult. If it is too large, it is more difficult to apply in more than one instance.

The project team members also assign value to these notions, but there is variance in enthusiasm for the concept in that it wanes the closer the team moves toward the production of the basic information object units. The issue is again one of granularity. It seems to the investigator that while the flexibility in application of an object is inversely proportional to its granularity, the object's efficiency of use and consistency in quality seem to be directly proportional to its granularity. This three-way relationship makes it hard to achieve desirable levels in all three properties at once.

While the interface design component of the team embraces learning objects with enthusiasm because of the ease with which they may enable users to select, sequence, and modify collections of objects, the production team members reject the inflexible presentation format, drab design interface, and the lack of choice for instructional strategy embodied in the basic information object as it is implemented in the QuickScience™ tool. Also, part of the production team's frustration with learning objects technology is that flexibility in design is easy to achieve when one is manipulating existing objects through data queries and reports, but more difficult to execute when one must manually modify individual fields in each record in the database.

Perhaps the most significant idea regarding the pedagogical dimension as it relates to the QuickScience™ instructional system is that its instructional strategies are embedded within the form of the learning object type. Although Barritt and Lewis (2001) allude to the possibility that learning strategies may be partially driven by the design of their learning and information object designs, Merrill and the ID2 Research Team (1996) and Murray (1998) insist that instructional strategy must be independent of the form of the learning object.

The problems of management, selection, and retrieval of yet another independent variable as learning objects are collected and prepared for delivery are far too large a burden in the opinion of the development team for users seeking a tool to increase the speed, efficiency, and simplicity of their instructional tasks. The embedding of learning strategies into the learning object's form, while initially unintended, is adopted with enthusiasm by the development team precisely because it offers the teacher using the tool increased speed, efficiency, and simplicity.

The fact that is easy to overlook in this discussion is that the QuickScience™ design team developed and devised the implementation of three entirely new learning object types beyond the original Cisco model. The new types were considered necessary precisely because of the limitations in learning strategies found in the original model. As the team struggled with the technical design of the new data types, they recognized the compatibility of the learning strategy components with the technical requirements of its data record. Once the connection was made, a conscious decision was made to model the object design on the design of the learning strategy and to embed the strategies into the form and presentation of the object. The development of the model went easily, and its successful implementation led to the evaluation, adoption, and implementation of two other types.

Technological Dimension

What technological concepts are important to integrated learning object-based instructional systems, and how are they reflected in practice?

Performance-centered design serves as the foundation of the tools teachers and others will need as responsibilities, performance expectations, and requirements for accountability grow. Colbert et al. (1990), Gery (1995), and Hannafin et al. (2000) recognize the importance of placing support tools into the context of the task they are to support as a means of improving the efficiency and quality of the tool user's performance. In the opinion of this investigator, the design team strives to provide QuickScience™ tool users a system for performing the tasks that exploit their familiarity with the common tasks of the teacher and other universal metaphors in order to enable them to perform those tasks more efficiently, with little confusion or uncertainty, and with measurable improvement in results. This is accomplished while using the tool's uncomplicated interface to shield the immense complexity and sophistication of the technological processes, making the performance improvement possible.

The benefits from use of the QuickScience™ instructional system are mostly for the teacher at this stage in the tool's development. Subsequent version redesign plans include a thorough reexamination of the learner’s tasks and the role the tool’s learner interface plays, or should play, in facilitating better performance.

An important function of such tools is the conveyance of heuristic approaches to work processes from within the ontological context of the job environment. Jackson (1999) and Letson (2001) provide analysis methodologies for framing the ontological context of a performance-support tool. The graphical design elements making up the QuickScience™ tool’s user interface, the tone, relevance and selection of support elements, and the prominence of access to key functions set the ontological undercurrent and heuristic direction of the teaching process for science education in a standards-driven curriculum.

Metadata, databases, and rapid prototype design permit immense flexibility and responsiveness to change in the development process for performance support applications. Letson (2001), Recker et al. (2000), Quinn and Hobbs (2000), and Yacci (1999) describe the roles of metadata in performance-support tools and explore the issues of metadata taxonomies and standards in relation to improving the functionality of the applications using it. Metadata is at the heart of the functionality of the QuickScience™ instructional system. It enables the robust search, evaluation, and selection features that maximize the user’s access to the tool’s instructional resources. It lies behind the resource management functions associated with the teacher’s student Web site and it accelerates the modification, enhancement, and evolution of the tool itself by the developers. In fact, the QuickScience™ development team is anxious for the international standards bodies to expand the scope and functionality of the metadata specifications by providing for a more robust taxonomy and more intelligible vocabulary for metadata property descriptions and properties. The team has already forged ahead with customized implementations of metadata properties but has taken care to incorporate the design improvements to the database in ways that do not preclude adoption of new standards as they evolve.

Adelman and Riedel (1997), Tripp and Bichelmeyer (1990), and Wilson et al. (1993) explore new design models for application development. These design models focus on flexibility and responsiveness in adjusting to modifications in function and evolutions in design requirements while reducing the time required to get operational models in front of key decision makers for cyclical evaluation.

The leadership of the QuickScience™ project employs a cyclical development process. There is a range of comfort with this process, particularly the irregular, unperiodic nature of it, within the design team. The members expressing the most discomfort are the members of the team directly involved with resource production, while those involved with the interface design express a marked preference for this method of development. Some of the discomfort among the production team stems from the uncertainties about the scope of their roles and frustration with the effect this fluidity has on the planning process, which is something frequently addressed in the literature. However, much of the discomfort comes from an unanticipated direction. While change and revision is a relatively painless process when it involves moving elements around on a layout, or restructuring a sequence of tasks in the interface, it can be a very painful, laborious task for the team members responsible for modifying all of the content, and often, the content development process, in order to accommodate design changes that may not even be permanent. The adoption of the learning object model, especially in its early phase when there was only one learning object type, is described by production team members as an enthusiasm-killing event. Some of this disappointment comes from the sheer quantity of the tedious and repetitive work. This investigator also believes that, given the visual arts background of the project's content coordinator and her affinity for creative composition in her screen designs, the change simply removed her from the elements of the design process that motivates her. It instead placed her into the center of a seemingly endless task, the unstimulating character of which was anathema to her. These circumstances call for a serious reevaluation and redesign of that section of the QuickScience™ learning system's input tool to provide designers a more *what you see is what you get* (WYSIWYG) interface with greater automation of repetitive tasks.

Cultural Dimension

What cultural concepts are important to integrated learning object-based instructional systems, and how are they reflected in practice?

The revolt against instructional design and the conditions for the successful diffusion of innovation seem to fit together in a natural sequence. If the designer has truly rejected the security of the traditional instructional design process for another methodology, the elements of diffusion may serve as a reality check for the validity of the output of whatever process, or combination of processes, the designer has embraced. Ultimately, the elegance of a design or attractiveness of a technological solution are meaningless if the tool has little chance of adoption.

Gordon and Zemke (2000) and Olcott (1999) characterize the growing dissatisfaction on the part of learning system designers and their clients with the traditional instructional design models while Rogers (1995) proposes an approach for gauging the likelihood of successfully diffusing the new model.

The QuickScience™ instructional system reflects, at every opportunity, the theme of embracing a new model for achieving success in the preparation and delivery of standards-based science instruction. The tool's flexibility, ease of use, and extensively validated content for learners convey in concrete terms the tool's relative advantage over current approaches: its compatibility with not only what the experienced teacher knows about classroom instruction, but also with models and metaphors familiar to the novice teacher as well. These generic models mask the complexity of many tasks with familiar and easy-to-understand interface elements. Finally, the tool provides the teacher a risk-free environment in which to experiment or practice instructional methods in ways that would otherwise be impractical because of the time required to gather, manually modify, and organize materials.

Pragmatic Dimension

What pragmatic concepts are important to integrated learning object-based instructional systems, and how are they reflected in practice?

The essence of the evidence from the data regarding the pragmatic dimension is that there are forces external to the QuickScience™ tool that play significant roles in both the likelihood of its adoption by users and in the nature of the development of the tool itself. The response by the design team to the former often shapes the character of the latter.

Bothun (1999), Farrington and Yoshida (2000), Hawkins (1999), and Katz (1999) describe the developing tension between learning organizations and their instructional developers. They also identify the pressures on the producers of learning programs from an increasingly competitive learning marketplace.

The pragmatic influences on the nature of the QuickScience™ instructional system vary slightly from the environments described in the literature, but do reflect the nature of rapidly evolving spot markets of demand with narrow requirements and finite time constraints. The performance-support elements of the tool are wholly grounded in the very real, very pragmatic solutions to common performance problems. The speed with which the user can perform large and complicated tasks with the tool frees the teacher to provide more of the interpersonal interaction that fosters better learning. The advent of standards-based testing in science makes adoption of the tool attractive, but the implementation of accountability measures associated with performance in science education makes adoption of the tool compelling.

Limitations of Study

One limitation of the study is that the qualitative approach and highly subjective analysis make generalization of the findings to many other situations difficult. It is not completely impossible because the study is grounded in a research-supported theoretical framework.

Another limitation of the study as it has been executed is the unique character of the performance problem. The mandated standards-based testing with performance-based accountability standards, addressed by a federally funded grant-based project, limits somewhat the extendability of the problem solution as a whole to another case. However, smaller aspects of the investigation may prove valuable to practitioners with similar problems.

Although there is triangulation of the data with interview transcripts, screen analyses, and document analyses, all of these were conducted by the investigator, who also happens to be a member of the project team under examination. The extensive theoretical framework for the investigation that also extends throughout the collection and analysis protocols should mitigate the effects of user bias and selectivity and, in fact, should be offset somewhat by the depth of investigation and intimacy of the investigator with the details and dynamics of the project under investigation.

Meaning for Practitioners

The experiences of the QuickScience™ project development team as they have been analyzed in this study through Hannafin et al.'s (1997) five dimensions of grounded instructional design may contain meaningful insights of use to others engaged in similar projects. The unique conditions of this study may present some difficulties in making generalizable statements in all cases, but there are some points that could prove valuable to others.

Among the most important suggestions for teams about to embark on collaborative, cyclical-design instructional system projects is to incorporate activities that address Rogers' (1995) five elements critical to the diffusion of innovation–relative advantage, compatibility, simplicity, trialability, and observability–into initial team building processes. It is important for the team itself to have a common sense of the value and importance not only of the project, but also of the intended approach to its development.

Another suggestion related to team dynamics in a cyclical development environment is that the project team members must be apprised at the very beginning of the project's work processes and approach. They must be clear that while the establishment of critical features, requirements, and goals may occur early in the project, the project may shift direction several times. Goals and requirements may emerge, grow, or recede in importance in response to external forces such as changes in client specifications or as the result of knowledge and insight gained in the development and examination of prototypes. The flexibility and adaptability of the technologies employed in learning object-based projects multiply the creative possibilities for designers, and the decision to settle on a final, production version of a project must be delayed as long as feasible to take advantage of the innovations that emerge from this creative process. Certainly, this flexibility comes at a cost in efficiency that must be weighed against the pragmatic requirements of the project. Also, decisions regarding the makeup of the team must take into account not only the proficiency of the candidates in their respective specialties, but also their degree of comfort with an evolutionary development approach that includes fluid schedules and changing requirements.

Another issue related to creativity and flexibility in the development process for such a project is that of the character of the tools used in the development of the project. In the case of the QuickScience™ project, the input tool the team developed for the content of the reusable information objects was both effective and efficient, but provided no stimulation to the content developers. In fact, it was universally denigrated as sheer drudgery to use. The development tools for such a system must be approached by the team designers with the same attention to the five dimensions of grounded instructional design (psychology, pedagogy, technology, culture, and pragmatism) as the tool being produced for the end user. Attention must be paid to integrating performance support, including embedded and intrinsic elements as well as presenting rich and stimulating interfaces that both enable and encourage visually creative approaches to the content.

One final suggestion for teams embarking on projects similar to the QuickScience™ project has to do with the notion of communicating fundamental concepts among a group of highly trained and skilled specialists. Some fundamental concepts related to the character of the project are almost certainly present in the cognitive structures of the team members. They are most likely embedded in layers of subsequent knowledge and experience that not only obscure access to the essence of the concept, but also color the concept in many ways. It may prove beneficial to the team to review explicitly the most important fundamental concepts very early in the process. The team should explore the role these concepts play from the context of the project's instance of the five dimensions of grounded instructional design.

Recommendations for Future Research

Several issues emerge from the investigation that do not fit within the framework and scope of this study but merit serious investigation because of their importance to the study of the nature of the translation of instructional design concepts into practice. One such issue is that of the nature of project management in collaborative instructional design projects. It is apparent that if organizations abandon the traditional instructional design model (which is essentially a linear process that meshes nicely with current project management practices) for cyclical, iterative design models, they will require a project management approach that accommodates the irregular, "starting over again, but from a different place" character of this process.

A project management-related issue emerged from the study as an area that suggests exploration in response to the advances in the technology used in QuickScience™ and its associated work processes. The issue is that of project team dynamics in a process that is both highly technical and highly creative in nature. The problem seems to be one of defining a work process and developing supporting tools that foster creativity within the pragmatic constraints of time and resources while exercising an acceptable degree of managerial control for directing creative efforts.

Another issue is related to the common problem of knowledge elicitation from experts in the development of expert systems. The problem is the nature of what has come to be called by interested members of the project development team, for lack of a more descriptive term, *automaticity*. The term refers to the deeply buried special knowledge that experts employ automatically, without conscious elaboration and without explicit discussion, in the execution of skills requiring that knowledge. It is the characteristics of the combination of that special knowledge, its activation mechanisms, and creative application that merit investigation by anyone who works with people who seem to exhibit special talents for resolving complex problems.

Finally, the richness in potential for developers of learning object-based instruction in the expansion of metadata taxonomies and associated vocabularies demands extended effort in its investigation. This field will prove useful to a new class of metaknowledge workers.

Summary

The purpose of this study is to determine how theoretical concepts underlying integrated learning object-based instructional systems translate into effective practice. The investigation relies on a theoretical framework consisting of the five dimensions of the grounded instructional design model developed by Hannafin et al. (1997): (a) psychological, (b) pedagogical, (c) technological, (d) cultural, and (e) pragmatic. The model enables a systematic collection, organization, and analysis of data around this framework.

The analyses of the data support a conclusion that this approach permits the development of a fairly accurate representation of the subject while providing useful answers to the main question and its five subquestions. The answers are that the underlying theoretical concepts can be best translated into effective practice through (a) conscious discussion and (b) periodic application of the framework as a heuristic guide, not a procedural blueprint. Perhaps its greatest value is in focus and consensus building and in the reactivation of important schema to facilitate access to underlying knowledge that easily gets obscured in the day-to-day problem solving associated with a large, complex, collaborative project such as QuickScience™.

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APPENDIXES

Appendix A

The University of West Florida Institutional Review Board for Human Subjects Approval

Appendix B

Design Tool Review Form

Design Tool Review Form

Name of Design Tool:

Project Director for Design Tool:

Design Tool Creation Date:

Version:

Reviewer Name:

Psychological Dimension Questions –

1. What implicit underlying psychological concepts are evident in the tool's approach to user tasks?

2. How does the design tool overtly express underlying psychological concepts in the primary user interface and what concepts are addressed?

3. How does the design tool overtly express underlying psychological concepts in user supports and what concepts are addressed?

Pedagogical Dimension Questions –

4. What implicit underlying pedagogical concepts are evident in the tool's approach to user tasks?

5. How does the design tool overtly express underlying pedagogical concepts in the primary user interface and what concepts are addressed?

6. How does the design tool overtly express underlying pedagogical concepts in user supports and what concepts are addressed?

Technological Dimension Questions –

7. What implicit underlying technological concepts are evident in the tool’s approach to user tasks?

8. How does the design tool overtly express underlying technological concepts in the primary user interface and what concepts are addressed?

9. How does the design tool overtly express underlying technological concepts in user supports and what concepts are addressed?

Cultural Dimension Questions –

10. What implicit underlying cultural concepts are evident in the tool’s approach to user tasks?

11. How does the design tool overtly express underlying cultural concepts in the primary user interface and what concepts are addressed?

12. How does the design tool overtly express underlying cultural concepts in user supports and what concepts are addressed?

Pragmatic Dimension Questions –

13. What implicit underlying pragmatic issues are evident in the tool’s approach to user tasks?

14. How does the design tool overtly express underlying pragmatic issues in the primary user interface and what issues are addressed?

15. How does the design tool overtly express underlying pragmatic issues in user supports and what concepts are addressed?

Appendix C

Document Review Form

Document Review Form

Title of Document:

Document Creation Date:

Revision:

Creator of Document:

Intended Purpose of Document:

Reviewer Name:

Psychological Dimension Questions –

1. What implicit underlying psychological concepts are evident in the document’s approach to user tasks?

2. How do the documents overtly express underlying psychological concepts related to the design of the tool?

3. How do the documents address the introduction of explicit psychological concepts to the primary user interface?

4. How do the documents address the introduction of explicit underlying psychological concepts in user supports?

Pedagogical Dimension Questions –

5. What implicit underlying pedagogical concepts are evident in the document’s approach to user tasks?

6. How do the documents overtly express underlying pedagogical concepts related to the design of the tool?

7. How do the documents address the introduction of explicit pedagogical concepts to the primary user interface?

8. How do the documents address the introduction of explicit underlying pedagogical concepts in user supports?

Technological Dimension Questions –

9. What implicit underlying technological concepts are evident in the document's approach to user tasks?

10. How do the documents overtly express underlying technological concepts related to the design of the tool?

11. How do the documents address the introduction of explicit technological concepts to the primary user interface?

12. How do the documents address the introduction of explicit underlying technological concepts in user supports?

Cultural Dimension Questions –

13. What implicit underlying cultural concepts are evident in the document's approach to user tasks?

14. How do the documents overtly express underlying cultural concepts related to the design of the tool?

15. How do the documents address the introduction of explicit cultural concepts to the primary user interface?

16. How do the documents address the introduction of explicit underlying cultural concepts in user supports?

Pragmatic Dimension Questions –

17. What implicit underlying pragmatic issues are evident in the document's approach to user tasks?

18. How do the documents overtly express underlying pragmatic issues related to the design of the tool?

19. How do the documents address the introduction of explicit pragmatic issues to the primary user interface?

20. How do the documents address the introduction of explicit underlying pragmatic issues in user supports?

Appendix D

Subject Interview Form

Subject Interview Form

Subject's Role in the Project:

Educational background, including relevant specialized training:

Professional experience (in years) in training or education:

Professional experience with this organization:

The interview questions are grouped around perspectives based upon the five dimensions of grounded instructional design:

1. Psychological
2. Pedagogical
3. Technological
4. Cultural
5. Pragmatic

Within each dimension, examples of principles associated with it are mentioned to explore:

1. If you believe they are expressed in the tool,
2. If you recall whether any of these principles were discussed by the development team during the development of the tool, or
3. If you believe opinions held by development team members about those principles may have contributed to the design and development process.

There are three areas in which evidence of such expressions are sought:

1. The functionality or features of the QuickScience™ tool.
2. References to specific related principles in the user interface.
3. References to specific related principles in the user support elements.

Psychological Dimension –

- Information Acquisition – physiology of cognition
- Knowledge Representation – exemplars, schema, mental models
- Knowledge Organization & Individual Differences –
    - subsumption,
    - mental maps,
    - preferred styles & patterns of construction,
    - generic tasks

- Context –
    - social learning,
    - structural holism,
    - stories,
    - well-structured problem space

Pedagogical Dimension –

- Constructivist Orientation –
    - method or philosophy?
    - cognitive flexibility,
    - collaborative learning environments
- Knowledge Objects as
  Instructional Design Components –
    - selection,
    - sequence,
    - transactions,
    - separation of content and strategy, design at pedagogical, not media level.
- Instructional Strategies – Relevant proximate subsumers, chunking, spatial & bridging strategies

Technological Dimension –

- Performance Support –
    - performance-centered design,
    - searching,
    - processing,
    - manipulation,
    - communication
- Knowledge Operations in Technology-Based Tools –
    - representing
        - objects,
        - events,
        - relationships,
        - concepts,
        - goals,
    - metaknowledge,
    - methods,
    - scripts,
    - control knowledge,
    - heuristics,
    - ontologies

- Metadata –
    - taxonomies,
    - interoperability,
    - purpose,
    - requirements for use,
    - granularity,
    - vocabulary
- Developmental Methodology –
    - rapid prototyping,
    - iterative cycles,
    - design-by-repair?

Cultural Dimension –

- Revolt against traditional ID –
    - slowness,
    - content independent,
    - questionable efficacy,
    - wrong world view
- Diffusion of Innovation
    - relative advantage
    - compatibility
    - complexity
    - trialability
    - observability

Pragmatic Dimension Questions –

- Market Forces –
    - pace of change,
    - global competition,
    - accountability,
    - market niches
- Production Rate –
    - development to delivery ratios,
    - cost recovery cycles
- Increasing shortage of experience – unintended consequence of productivity gains

Appendix E

Informed Consent Form

Informed Consent Form for Subjects of a Research Study
Conducted By David B. Dawson,
Doctoral Candidate, College of Professional Studies
The University of West Florida.

Title of Research: THE TRANSLATION OF THEORETICAL CONCEPTS UNDERLYING LEARNING OBJECT-BASED INSTRUCTIONAL DESIGN TOOLS INTO PRACTICE

I. Federal and university regulations require us to obtain signed consent for participation in research involving human participants. After reading the attached letter and statements in section II through IV below, please indicate your consent by signing and dating this form.

II. Statement of Procedure:

Thank you for agreeing to participate in this research study. The purpose of this research is to examine how theoretical concepts related to learning object technology and instructional design are translated into practice. The development team of which you are a member represents a case in this study and your input represents a component of that case.

I understand that:

(1) The researcher will conduct a personal interview with the subject for the purpose of discussing the subject's experiences and opinions as a development team member regarding the processes and products associated with the project for development of a learning object-based instructional design tool.

(2) The researcher may both take notes of the interview and record the interview with an audiocassette recorder for later transcription into notes.

(3) Notes from the personal interviews and those created from the audiocassette recordings will identify the subjects only by the role they played in the development team of which they were a member. References to the interviews in the study will contain only generalized information regarding the learning and cognitive theories to which they ascribe and experience with the instructional design process Every effort will be made to remove all references to personal identities in the interview notes and transcriptions of the interview audio cassettes.

(4) Each subject will be hand delivered two copies of an informed consent form, which will also be personally read to them by the investigator. The subjects will sign both copies prior their interviews.

(5) The subjects will retain one copy and the investigator's copy will be filed together with the other subjects' forms in a file kept separate from the rest of the investigative materials in the investigator's office. The forms and interview materials will be kept secure for a period of five years from the approval of the dissertation, after which they will be destroyed in accordance with University policy regarding the disposal of confidential documents.

III. Potential Risks of the Study:

(1) There are no foreseeable risks involved with the study.

IV. Potential Benefits of the Study:

(1) An examination of implementation into practice of the concepts underlying learning object-based instructional design tools may yield insights useful to other institutions contemplating adoption of these practices.

(2) Insights gained from the study may also be useful to developers in refining and adapting such design tools.

(3) Finally, such insights may illuminate critical intersections of theory and practice in this field for researchers.

V. Statement of Consent: I certify that I have read and fully understand the Statement of procedure given above and agree to participate as a subject in the research described therein. Permission is given voluntarily and without coercion or undue influence. It is understood that I may discontinue participation at any time. I will be provided a signed copy of this consent form.

If you have any questions or concerns please contact the researcher:

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Pensacola, FL 32514
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ddawson@uwf.edu

______________________________ ______________
Participant’s Name (Please Print) Date

____
Phone Contact

Appendix F

The University of West Florida's Institutional Review Board Approval

for Alternate Protocol