A Reusable Learning Object Design Model for Elementary Mathematics

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Abstract

The purpose of this qualitative study was to measure the effectiveness of a new reusable learning object design model for elementary mathematics. This study was motivated by the lack of general reusable learning object design models and, specifically, elementary mathematics design models that include both technical and learning specifications. The research design method was a qualitative Delphi technique and included participants across the United States and other countries. Ten participants were provided the design model and a questionnaire to analyze the effectiveness of the model on the online instructional design process. Two rounds of questionnaire responses and model refinements were conducted at which point a consensus was reached. As a result of the data collected, the elementary mathematics reusable learning object (EM-RLO) design model was modified to focus equally on technical and learning specifications for designing elementary mathematics reusable learning objects. The results of the Delphi process indicated that the design model did contribute to the online instructional design process by introducing a pre-assessment procedure at the beginning of the design process. This model's placement of the pre-assessment function has the potential to result in the creation of more effective and beneficial instructional designs for online learning in elementary mathematics.

Dedication

This dissertation has been dedicated to my children, Melanie, Alex, and Madison. I hope this work will inspire them to *reach for the stars* when it comes to excelling in and obtaining their education.

Acknowledgments

I have definitely taken a trip down many different roads on this journey to completion. The roads range from long to tiring, exhausting to exciting, and non-motivating to motivating. However, the trip was rewarding. I have several individuals to thank for getting me through all the different avenues and dead end streets of this journey. Above all, I thank God for guiding me through this process. None of it would have been possible without Him. I want to thank my previous mentor, Dr. Elena Kays, for giving me my start on the ideas that would ultimately become my focus for this dissertation and taking me under her wing by becoming my M.O.M. (Motivator of Me). I want to thank my current mentor, Dr. Sonja Irlbeck, for guiding me in the right direction and allowing me to take control of my own destiny. I could not have completed the process without the valuable input of both committee members, Dr. Albert Ingram from Kent State University and Dr. Vernon Czelusniak (Dr. C) from Capella University. I would also like to thank my editor, Dr. Alicia Nicki Washington from Howard University for prompt service and the long hours committed to helping me make deadlines and reach goals. I want to thank my research participants because without them, there would not have been a validated or completed dissertation. I would also like to thank a host from Capella University classmates and coworkers who offered advice as well as ideas on certain topics and issues relating to my dissertation work.

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CHAPTER 1. INTRODUCTION

Introduction to the Problem

Middle and high schools are beginning to use online delivery to complement curriculum (Boyle, 2003). One method of delivering online learning is by using learning objects (LO), which are digital learning resources shared and accessed through the Internet and reusable in teaching and learning contexts (Haughey & Muirhead, 2005). Middle and high school students benefit from using computers to complete assignments. According to Goldberg, Russell, & Cook (2003), a majority of students would rather use computer-based than traditional educational methods. Learning objects are also commonly used in secondary and middle schools than in elementary schools (Nurmi & Jaakkola, 2005).

As instructors and instructional designers discovered multiple uses for a single LO, they began developing LOs for use in more than one learning activity. These LOs, known as reusable learning objects (RLOs) are similar in definition and use to LOs. Some authors use both terms interchangeably. The term *learning object* was first coined, and then it evolved to RLO. For the purpose of this research, the term *reusable learning object* was used to support the primary focus, to create a design model for developing RLOs for elementary mathematics to determine whether it enhanced the online instructional design process. Haughey & Muirhead (2005) made the point that the use of learning objects varies depending on the age of the learner:

The context for employing learning objects or RLOs differs between the K-12

> sector and postsecondary sector and affects the design of learning objects. Unlike more adult settings where learning objects can be used by learners independently, much of the current efforts in the K-12 sector have been to design learning objects for face-to-face classroom settings. This change in context and the requirement to design for incorporation into pre-existing learning strategies has created additional complexities for designers who must take into account the culture and climate of school classrooms. (p. 2)

RLOs have advantages over standard instructional materials, including flexibility in constructing courses from a number of smaller learning objects for use in a number of different circumstances and by a greater number of users. A shortage of RLOs exists in elementary education, particularly in mathematics. In order to address this deficiency, more research needs to be conducted to determine how RLOs could potentially aid in elementary math achievement.

Background of the Study

RLOs are poised to become reusable chunks of instructional content of choice for online learning, but technical standards and venture capital are not enough to encourage their use to promote learning (Wiley, 2001); technology use should be guided by instructional principles. Wiley (2001) stated that the potential of reusable learning objects as an instructional technology is good, but will never be realized without a balanced effort in technology (technical specifications) and instructional design (learning specifications) areas.

In addition to the lack of a balanced effort between technical and learning specifications in online instructional and RLO designs, elementary math RLO design models have not been considered for enhancing the online instructional design process or creating effective online math RLOs. Through evaluating the learning effects of RLOs in different classroom settings, Pan, Gay, & Saylor (2005) demonstrated that different types of instructional design fit different educational needs. Educators' strategies for integrating RLOs into curriculum depended on the subject area and educational level of students. These differing strategies result in students using available material in various ways and with different learning outcomes. The Pan et al. multi-stage study (2005) also examined how to adopt appropriate combinations and granularity when designing LOs for user groups.

Examples of successful RLO design models for specific users and uses exist, including college geometry or high school Microsoft Excel® training. Design models that include both technical and learning specifications of the instructional design process, such as elementary math, are not common. Kay and Knaack (2005) studied the development of learning objects for secondary school students. Of more importance to students and teachers were the learning features of the multi-component model rather than technical features. This result was not predicted by previous literature, where a heavy bias has been placed on more technical issues such as metadata, reusability, and accessibility (e.g., Boyle, 2003; Bradley & Boyle, 2004; Littlejohn, 2003; Polsani, 2003). The authors also noted relatively little research on design principles of RLOs, as they were recommended but rarely evaluated (p. 231). Designers also divided guiding

fundamental structures, emphasizing either a learning specification or a technical model, but not both (p. 231). These conclusions support the need for further research.

Wagner (2002) supported the need for more design strategies that include both technical and learning aspects of RLOs. According to Wagner, the primary reason practitioners did not implement learning object design was because they lacked technical knowledge to interpret and apply technical guidelines. Professionals are still waiting for useful, widely accepted processes and standards.

According to the literature on RLO design theories and models, instructional designers tend to focus on either technical aspects or learning aspects of RLOs. Very few designs provide both technical and learning procedures. The study conducted here aimed to develop a RLO design model that includes both learning and technical procedures for the elementary math discipline and added to the breadth of knowledge of online instructional design.

Statement of the Problem

In recent years, the educational potential of RLOs has been examined, but relatively little research has focused on the design and developmental process, particularly in elementary mathematics. According to Bannan-Ritland, Dabbagh and Murphy (2000), RLOs that help students excel have not yet been fully explored at the elementary school level. Kay and Knaack (2007) identified very few papers documenting the design and development of learning objects. Recent authors (MacDonald, Stodel, Thompson, Muirhead, Hinton & Carson, 2005; Bradley & Boyle, 2004; Cochrane, 2005;

Krauss & Ally, 2005; and Metros, 2005) found three patterns that emerged from the studies. First, only higher education students have been examined (Bradley & Boyle, 2004). Second, technical features are emphasized before learning features (Cochrane, 2005). Third, there is a clear absence of systematic formal evaluation (Krauss & Ally, 2005). A need exists to merge relevant aspects of theories to create an RLO design model focusing on technical and learning features which may encourage a change in how RLOs are designed for elementary mathematics that would enhance the instructional design process for online learning at the elementary level. Current literature and research on instructional design theories used to develop RLOs show a gap in how and to what extent a design model for RLOs in elementary mathematics can manifest principles and effective practices of instructional design. This study aimed to close that gap by demonstrating the effectiveness of the relationship between design models for RLOs in elementary mathematics and the online instructional design process.

Purpose of the Study

The purpose of this study was to develop and validate a RLO design model for elementary-level mathematics, including technical aspects and learning design principles and effective practices. The development of this model utilized standards and procedures from the learning object design and sequencing theory (LODAS) (Wiley, 2000), sharable content object reference model (SCORM) standards (Rustici, 2007), Cisco Systems RLO strategies (2004), and National Council of Teaching Mathematics (NCTM) (2004). The

design model included theory that guides instructional use of LOs and technical guidelines for creating RLO designs.

Rationale

This study should add new and effective knowledge to instructional design processes for online learning. Currently, there are models focusing on either the technical aspect or learning aspects of RLOs. Learning principles (Wiley, 2000) and technology (Cisco Systems, 2004) are equally important when designing and building RLOs. In addition, most RLO design models target higher education or distance-based learning. The proposed RLO design model highlighted both the learning and technical aspects of RLO design for elementary mathematics.

Research Questions

The research questions addressed in this study were

1. To what extent does the RLO design model for elementary mathematics manifest effective practices of instructional design for online learning?
2. How might a new RLO design model for elementary mathematics enhance the online instructional design process?

Theoretical/Conceptual Framework

Reigeluth (1997) defined instructional design theory as anything that offers guidance for improving the quality of any mechanism used to help someone learn (p. 44).

For the purpose of this study, several design theories and strategies were utilized to create a RLO design model. The development of the RLO design model consisted of one theory and three standards and procedures, including the learning object design and sequencing theory (LODAS) developed by Wiley (2000), which centers on learning techniques of RLOs; SCORM standards and Cisco Systems RLO strategies, which highlight technical techniques; and the National Council of Teaching Mathematics (NCTM) Elementary principles and standards, which specify guidelines for developing instructional strategies in elementary mathematics.

Significance of the Study

Developing a RLO design model for elementary mathematics presented several important challenges for this study, including the development of a more efficient and effective RLO design model, so that it may be used to create RLOs focusing on both technical aspects and instructional techniques. This study projected to add more efficient and effective elementary math RLO design procedures to instructional designs for online learning by introducing a design model that could examine the fundamental process of developing small re-usable elements of learning content. The study also demonstrated technical techniques, such as developing procedures to demonstrate how or where the RLO did function.

The results of testing this new design model extended current knowledge of RLO design strategies and theories, resulting in more cost-effective RLO development. In addition, this study allowed more RLO exposure to the elementary levels of mathematics

education. The design model provided guidelines that can be used to develop RLOs that can enhance mathematical skills and knowledge of elementary students. Lastly, this study potentially added to limited research on positive impacts of RLOs in elementary mathematics, and the merging of technical and instructional use guidelines. This work also added new knowledge to the principles and effective practices of RLO model design, benefitting instructional designers, teachers, and students.

Definition of Terms

Cisco Systems RLO Strategy. A strategy that emphasizes RLOs should focus on a single task and be similar to a short lesson. Cisco Systems requires that RLOs contain content, practice, and assessment items. Their specification also provides standard formats for teaching various RLOs. Objects vary according to the knowledge being taught and objectives of instruction (Barritt, Lewis, & Weiseler, 1999).

Delphi Technique. A series of carefully designed questionnaires interspersed with information summaries and feedback from preceding responses (Stuter, 1996), designed to obtain group input for ideas and problem-solving.

Instructional design for online learning. A systematic process for translating learning principles into plans for online instructional materials and learning (Reigeluth, 1999).

Learning Object Design and Sequencing Theory (LODAS). An instructional design theory (Wiley, 2002) that reviews, synthesizes, and combines existing instructional design theories with new work. LODAS provides guidelines for the analysis

and synthesis of an undifferentiated content area, the application of which produces specifications for the scope and sequence of learning objects.

National Council of Teaching Mathematics (NCTM) Principles and Standards. Guidelines established by the NCTM to describe how mathematics is taught, how students should learn mathematics, and how to develop effective mathematics curriculum for K-12 students (NCTM, 2000).

Participant(s). The persons who agreed and met criteria to critique the RLO design model.

Reusable learning object (RLO). Specific chunks of content and code that represent an assessment, exercise, or instructional content that can be reused in other curriculum/lessons or learning activities (Wiley, 2002); small, independent, reusable chunks of knowledge which can be presented as units of instruction or information (Polsani, 2003).

Sharable Content Object Reference Model (*SCORM)*. A collection of technical specifications that enable interoperability, accessibility and reusability of web-based learning content (Rustici, 2007).

Assumptions and Limitations

The primary assumptions of this study was that there is a need for a RLO design model which gives equal value to both learning and technical aspects of RLOs for elementary mathematics, and that instructional designers were willing to implement a model to introduce online learning of RLOs to in-class learning environments. This study

was not conducted for other elementary subject areas and is not intended for levels other than elementary education. A limitation of this study was the design model appeared complicated at certain steps of the process. For example, the learning specifications process consisted of several steps or sub-steps to complete the development of an RLO. This model was intended to provide the basis for change in RLO design models for elementary mathematics.

Nature of the Study

The research method used in this qualitative study was the Delphi technique. This study was divided into three phases. In phase 1, the design model was developed. Phase 2 was the review and evaluation of the model by a panel of participants using the Delphi technique. Phase 3 of this study was a model refinement phase based on recommendations and comments (consensus) provided by the panel of participants.

Organization of the Remainder of the Study

The remainder of the study consists of Chapter 2, which reviews current literature on RLO design, development and use. Chapter 3 describes the qualitative Delphi technique research methodology. Chapter 4 examines the data collected and analyzed through rounds of the Delphi technique. Chapter 5 summarizes the results of data analyzed and discusses future research study recommendations.

CHAPTER 2. LITERATURE REVIEW

Introduction

Reusable learning objects (RLOs) for elementary students are new and developing arenas in distance learning. Online learning typically refers to adult-based education, and yet several learning techniques and tools are implemented in distance learning. One such tool is RLOs which can be used by teachers in elementary classrooms to provide elementary students with online learning opportunities (Roberts, 2004). RLOs, such as mathematics multimedia applications, aid teachers in traditional classroom environments by enhancing student knowledge (LOM, 2002). Although more RLOs are being developed in elementary education, the design models used to create them tend to focus on either technical specifications or learning techniques. Several models have been developed by individuals and companies. These models, which will be discussed further in this chapter, tend to lack vital techniques needed to create well-rounded and effective RLOs for the elementary environment (Pan, Gay & Saylor, 2005).

Research has not shown that a RLO design model exists that gives equal value to both the technical and learning aspects of RLOs. Models have been created for the development of RLOs, but tend to be general. More focus should be placed on student characteristics when creating RLOs. Previous math-based RLO design models were designed for traditional face-to-face elementary math courses. Barritt and Alderman's model (2004) is a good starting point for developing RLOs for mathematics, but more detailed procedures may be needed to create RLOs for mathematics. This chapter examines several areas of the literature about creating RLO design models. The review is

divided into four sections. First, design theories and strategies and instructional principles are reviewed to provide a detailed explanation of the technical specifications and learning procedures needed to develop a RLO design model. Second, mathematics principles and standards are examined to provide a focus on RLO design models for elementary math. Next, reusable learning objects and elementary math instructional strategies and methods are examined to provide the RLO design model with the necessary elementary mathematics-specific components. Last, the Delphi technique is defined to provide context about the research design for this study.

RLO Instructional Design Theories, Principles, and Standards

RLO instructional design theories, strategies, standards, and principles show favoritism regarding guidelines and models that demonstrate how to create RLOs. Most models focus on either the learning or content specifications or the technical specifications (how and where to display RLOs) of creation. Wiley (2000) stated,

> While groups like the Learning Technology Standards Committee exist to promote international discussion around the technology standards necessary to support learning object-based instruction, and many people are talking about the financial opportunities about to come into existence, there is astonishingly little conversation around the instructional design implications of learning objects. (p. 8)

Martinez (2000) also found that current design efforts for LOs avoid critical instructional design issues due to an unclear understanding of standards, strategies, and guidelines for

personalized learning. As a result, the need for an instructional framework for present LOs to achieve instructional objectives is ignored or overlooked.

To address this problem, two questions must be asked. First, how can LOs be presented in an instructionally sound manner if the presentation is not guided by the appropriate planning, learning, and instructional information? How can one design and develop LOs without understanding how they should be used or presented for instruction? Wagner (2002) addressed the paradigm shift that needs to happen by explaining that developing object-oriented learning designs involves a significant change from behavioral to cognitive perspectives and from objectivist to constructivist perspectives. The goal of complete and correct understanding is to get people to know the entities, attributes, and relations that exist, unbiased by their prior experience.

Constructivism enables designers to design instruction in a myriad of ways. Wagner (2002) stated, "This suggests that there are many ways in which to structure the world" (p. 6). As a result, there may be more than one correct meaning or understanding for students to attain. Learning is not a response to a stimulus, but is a process of understanding in this setting (Wagner, 2002).

A combination of the LODAS theory, SCORM, Cisco Systems RLO strategy, and NCTM principles and standards merged important elements for creating a new RLO design model, focusing on both learning and technical specifications. Both types of specifications ensured the design of a well-rounded and effective RLO. Each theory or principle favors either content/learning characteristics or technical characteristics of RLOs. The following section explains each theory or group of principles.

LODAS

Wiley's learning object design and sequencing (LODAS) instructional design theory addresses the issue of granularity (scope and design) and sequencing (combination) in learning objects (2000). By combining a number of existing instructional design theories, including elaboration theory (Reigeluth, 1999), work model synthesis (Gibbons, Bunderson, Olsen & Rogers, 1995), domain theory (Bunderson, 2002), and the four-component instructional design model (van Merriënboer, 1997), LODAS provides taxonomy and design guidance for different types of learning objects. These theories are extended by addressing two fundamental issues in the design of learning objects, granularity and sequencing.

The development of the LODAS theory is described in six categories. Each category (preliminary activities, content analysis and synthesis, practice and information presentation design, learning object selection or design, learning object sequencing, and loop back for quality improvement) includes several methods used to explain the individual category topic. For the purpose of this study, only the learning object selection or design category was discussed.

The select and/or design learning objects category of the LODAS theory is the group of methods that links specific problems, worked examples, and previously designed instruction to LO types. This category also provides guidance for the design of each LO type. Methods included are taxonomy of learning object types, learning object characteristics, learning object type definitions, and select learning object types and design learning objects (Wiley, 2000).