Canadian Journal of Learning and Technology / La revue canadienne de l’apprentissage et de la technologie, V33(2) Spring / printemps, 2007

Canadian Journal of Learning and Technology
Volume 33(2) Spring / printemps 2007

Embedded or linked learning objects: Implications for content development, course design and classroom use

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Abstract

Abstract:

This research explores the idea of embedding and linking to existing content in learning object repositories and investigates teacher-designer use of learning objects within one high school mathematics course in an online school. This qualitative case study supports and extends the learning object literature, and brings forward context-specific examples of issues around repository design, autonomy and self-containment, technical support and granularity. Moreover, these findings have implications for building learning objects and repositories that could better support teachers in their instructional design and pedagogical decision-making.
Résumé : La présente recherche étudie la possibilité d’effectuer un emboîtement et d’établir des liens avec le

contenu existant dans les référentiels sur les objets d'apprentissage et explore l'utilisation par les enseignants-concepteurs des objets d'apprentissage au sein d'un cours de mathématique du secondaire donné dans une école en ligne. Cette étude de cas qualitative appuie et vise la littérature sur les objets d'apprentissage et met en avant plan des exemples de questions touchant la conception de référentiels, l'autonomie et l'indépendance, le soutien technique et la granularité propres au contexte. De plus, ces conclusions ont des répercussions sur l'élaboration d'objets et de référentiels d'apprentissage qui pourraient mieux appuyer les enseignants dans le cadre de leur conception pédagogique et de leur prise de décision touchant l'enseignement.

Introduction

The development of learning objects is premised on the notion that users of these objects will link to them from a central repository, incorporating the links into content for site-specific use (Friesen, 2004; Wiley, 2002 a & b). The present research explored this commonly held premise using the following questions as a guide:

- How do online teachers use learning objects that are available in local and online environments and those that are linked from a central repository?
- How does the repository design of these learning objects support or hinder innovative use?
- How does embedding vs. linking affect student use/access of the learning object?

In this qualitative case study, the researchers interviewed one high school teacher who designed a Mathematics course for online delivery in an urban Alberta school. Informal discussions and semi-structured interviews (both face-to-face and by telephone) were held with the teacher. In addition, student movement in the course was tracked as part of its regular management process. It was anticipated that this tracking would allow the researchers to understand the links that students followed as they moved through the topics and accessed the various learning objects. However, for reasons which will be discussed later, this aspect of the study became less important and the focus turned to teacher/designer use of the repository. Additional sources of data for this study included the results of analyses done on the learning objects and the course, focusing on the instructional design, the integration of local resources (textbook and accompanying CD-ROM), and use of the learning objects housed online and in a learning object repository. To date, little research has been done on the pedagogical consequences of the numerous international learning object initiatives and their impact on thinking, epistemological and ideological implications, and teaching and learning (Friesen, 2004). The present research is a step toward filling that gap.

Literature Review

A number of researchers note that the digital age has enhanced our ability to create and distribute resources to personalize and individualize learning (Hannafin, Hill, & McCarthy, 2002; Martinez, 2002). Learning objects are a step towards realizing these possibilities. However, it appears that there is confusion as to what a learning object is (McGreal, 2004). Wiley (2002) suggests "Learning objects are elements of a new type of computer-based instruction grounded in the object-oriented paradigm of computer science" (p. 4). While this sets the generic scene that learning objects are part of computer-based instruction, it does not help to describe what forms they might take or what role they serve in

teaching, learning, and training.

Definitions vary, including everything from people as resources to small units of digital content in the form of pictures. Some view learning objects as primarily digital in nature (Martinez, 2002; Merrill, 2002; Wiley, 2002) while others include non-digital resources as learning object elements (Hannafin, Hill, & McCarthy, 2002; IEEE Learning Technology Standards Committee, 2005). According to some, learning objects are simply seen as "resources" (Hannafin, Hill, & McCarthy, 2002) while other researchers are more expansive, accepting elements such as environments, activities, processes, and software tools in their definitions (Bannan-Ritland, Dabbagh, & Murphy, 2002; Gibbons, Nelson, & Richards, 2002; IEEE LTSC, 2005).

Instructional context is also a point of contention in definitions. Some definitions recognize solitary media objects such as graphics, animations, and video clips as learning objects (Chitwood, May, Bunnow, & Langan, 2002; Gibbons et al., 2002). Acceptance of these instructionally-independent media as learning objects is based on the premise that teachers will provide the instructional context by assembling the learning objects into an instructional wrapper that would be useful, meaningful, and effective for their own situations. Others argue that a content object must incorporate integral instructional context if it is to be considered a learning object—i.e., "a mere picture is not a learning object because there is no instruction inherent in the picture" (Downes, 2003). For those learning objects which do incorporate instruction, size or granularity becomes a problem. How big is a learning object? Is it a course or a unit or a topic or a single concept? South and Monson (2002) offer some direction, indicating that learning objects need to be "granular enough to be useful in a variety of contexts, but aggregated enough to provide a robust exploration" (p. 225).

Although definitions vary, common characteristics also emerge. Chitwood et al. (2002) suggest that a description of learning objects, across the literature, includes the following criteria:

- Self-contained – each learning object could function by itself;

- Reusable – a single learning object may be used in multiple contexts for multiple purposes;

• Can be aggregated – learning objects can be grouped into larger collections of content, including traditional course structures; and

• Tagged with metadata – every learning object has descriptive information allowing it to be easily found by a search (p. 213).

Consistent in the literature are issues of modularity, re-usability, searchability, size, and learning. Learning objects are seen as "self-contained, reusable, high-quality learning chunks that can be combined and recombined in courses, learning activities and experiences, and assessments that meet a learner's immediate needs" (Chitwood et al., 2002, p. 203). Within these key characteristics, as Williams (2002) indicates, "what constitutes an actual learning object as part of instruction in a given context must be defined by the users of that learning object for it to have useful meaning for those users" (p. 87).

For the purposes of this study, the term "learning object" encompasses the widest definition of learning objects indicated in the literature, including both digital and non-digital resources, instructional objects at all levels of granularity, and objects with no integral instructional context. Moreover, this definition of learning objects includes "teacher-made" learning resources such as videos, activities, media objects, and so on. The notion of teacher-made resources is beginning to be explored, as authoring software such as iMovie®, FrontPage®, and Dreamweaver® become more commonly used by teachers. Teacher-created resources have the benefit of being site specific, learner specific, and concept specific. Resources can be built directly to address a just-in-time learning need and to assist students and teachers to bridge the gap between what a student already knows and what s/he needs to know to build personal knowledge through problem solving (Crichton & Li, 2004).

In recent years, the emphasis has been placed on the organizational / administrative side of the learning objects in terms of repository development and meta-tagging (Wiley, 2002a). Consistent with the researchers cited in this literature review is the caution that "up to now, developments have focused on technology rather than … learner-centric issues" (p. 152), which suggests that the promise of learning objects will not be realized until people shift their emphasis from metadata and standards to learning and the actual practices of educators as they attempt to use them in the field (Crichton & Li, 2004; Wiley,

2002).

With this shift, a critical dimension of learning objects is how they are used to support meaningful learning. It is the use that moves learning objects from being mere digital assets to integrated, valuable learning tools—from being generic “every things” to re-usable “some things”.

Chitwood et al. (2002) state that the concept behind a learning object approach to course design is to “put a pile of learning objects in front of a course builder … and watch courses emerge in creative ways” (p. 204). They also suggest the overarching value of learning objects rests in the potential of providing learning experiences which are:

Just enough – if you need only part of a course, you can use just the learning objects you need; Just in time – because learning objects are searchable, you can instantly find and take the content you need; and, Just for you – learning objects allow for easy customization of courses for an organization or individual. (p. 213)

Within this view is the implicit assumption that a teacher who wishes to use learning objects must shift from merely accessing content to being able to engage in aspects of instructional design. Bannan-Ritland et al. (2002) stress the importance of linking theory to practice in instructional design and development. Gibbons et al. (2002) suggest that it will not be until teachers, through training and ongoing professional development, begin to modify and individualize learning objects and incorporate them into their practice that learning objects will move from isolated digital assets to quality learning options and supports for students and teachers.

A mindset of teacher-based instructional design, with allowances made for teacher involvement in the creation, modification, and combination of learning objects, suggests two other critical dimensions—access and usability. Access to learning objects tends to be controlled through repository management software. It is the design and user friendliness of that navigation tool that prevents users (designers, teachers, students, trainers, etc.) from getting lost (Orrill, 2002) and provides affordances for use of the learning objects (e.g., selection, combination, etc.). Access and usability are major issues at this time as developers of learning objects and managers of repositories wrestle with

copyright, ownership, and other procedural concerns.

Learning object repositories are generally designed with the assumption that teachers will "link" to the resident learning objects—that is, all learning objects will remain in the repository and when teachers are building their lesson documents, they will simply insert pointers or URLs to the learning objects that meet their needs. Teachers can also "link" to learning objects that are not stored in repositories. There are advantages to using a "linked" philosophy (M. Mattson, personal communication, 2004): learning objects are maintained in a management system that is standardized and searchable; the integrity of the learning objects is maintained because they cannot be changed by unauthorized users; and ownership of the objects is established because the learning object never leaves the site.

In contrast, "embedded" objects are housed directly within a lesson document (e.g., a media object inserted into a Microsoft® Word document or PowerPoint® presentation) or with the lesson, on the same computer system. Embedded objects can be teacher-made objects or copies of the learning objects in repositories or from other Internet sources. Generally, embedded objects are easier to change and adapt to the specific context required by the teacher; however there can be issues of ownership, reusability, and searchability (M. Mattson, personal communication, 2004). For the purposes of this study, "embedded" is defined to mean that the learning object is an internal part of the lesson—that is, resident on the same computer system that holds the lesson; the term "linked" is defined as pointing to an external Internet source.

Whether linked or embedded, learning objects must be combined in such a way that quality, meaningful learning can be supported. Orrill (2002) states that learning objects offer an "ease of development, a high degree of interchangeability, and a higher degree of individualized learning than traditional group focused instructional interventions" (p. 131) cautioning that " our challenge is to provide an environment that is rich with learning experiences and resources" (p. 135). The literature suggests that it will be the development of this type of a learning environment that will be at the core of innovative and learner-centered instruction. Also consistent with the researchers cited in this literature review is the caution that developments have focused on technology rather than learner-centred issues. In recognition of the importance of research

in this area, a provincial government agency funded the present study of teacher use of a learning object repository created for use in Alberta schools.

Methodology

A case study approach to this research was chosen after careful consideration of the criteria for case research set out by Yin (2003). First, guiding questions were "how" questions

How do online teachers use learning objects that are available in local and online environments and those that are linked from a central repository? How does the repository design of these learning objects support or hinder innovative use? How does embedding vs. linking affect student use/access of the learning object?

Meeting a second criterion as indicated by Yin, situational context in this case was considered important. An in-depth study of a single online teacher as (s)he designed and implemented a lesson with a single class provides the thick and rich description that would provide "relatability"—i.e., allow others to relate the findings to their own contexts (Hisham, 2006). Although a multiple case replication study might be useful at a future date, the context of this seemed sufficiently "typical" or "representative" (Yin, 2003, p. 42) of learning object use, by technologically comfortable teachers in online and mainstream schools, to warrant a case study approach.

Finally, according to Yin (2003), a unique strength of a case study is the ability to integrate a variety of evidence sources. By following a single teacher there were multiple sources of evidence explored and included in the analysis, from learning object(s), documents, artefacts, observations, and interviews.

For the case, the researchers approached an online school in order to find and follow a teacher who might be interested in participating in the study. This venue was selected intentionally because we considered that online teachers were or would be more likely to make serious use of learning objects for instruction in their courses. The selected teacher / designer / participant was a technologically-experienced high school mathematics teacher who was developing a course using (a) learning object(s) from the LearnAlberta repository.

This case study involved a Grade 10 course, Mathematics 14, developed for an online and home education school in an Alberta city. According to the teacher/designer participant in this study, Mathematics 14 in the Alberta Program of Studies is intended for students who have previously failed Grade 9 mathematics. In addition to weak mathematical skills, the reading skills of students also tend to be low. For the purposes of this research, the teacher / designer was to use both linked and embedded learning objects in the creation of a mathematics course that would accommodate this target audience and be appropriate for online delivery.

Data collection consisted of four main phases including (1) a meeting and semi-structured interview with the teacher / designer to find out about the developing course, (2) a detailed examination of the Mathematics 14 course and a comparison between this and the Mathematics Continuum Learning Resource in the LearnAlberta repository (www.learnalberta.ca), (3) a semi-structured interview with the teacher / designer after course delivery, and (4) an exploration of the student tracking data automatically provided by the course-management system.

The first two procedures for data collection were intended to collect information to answer the first two research questions—how learning objects were used and how the design of the repository and the learning object helped or hindered the design efforts. The third step, conducted after the course delivery, was to collect information from the teacher / designer's reflection on the process and the learning to help deepen our understanding of issues brought forward in earlier discussions. The final procedure mapped to the last research question about student use of the learning objects in the course.

Results and Discussion

The first meeting and interview with the teacher/designer provided an orientation and familiarization for the content and structure of the Mathematics 14 course. During this meeting, the teacher / designer made it quite clear that she had based the course primarily on a single LearnAlberta resource called the Mathematics Continuum. This learning resource, developed specifically for this repository, covers 21 concepts required by the Mathematics 14 program of studies, further broken down into units, topics, and scenes. A scene is actual instruction for a given topic and can consist of a multimedia explanation, one or more interactive questions, or a brief game. The seven different levels of granularity in this resource, as reflected by the hierarchical organization of units, topics, and scenes, are shown in Figure 1.

This first meeting with the teacher / designer and a subsequent detailed examination of the course helped to determine which parts of the Mathematics Continuum learning resource had been used, which ones had been linked or embedded, and which levels of granularity had been used.

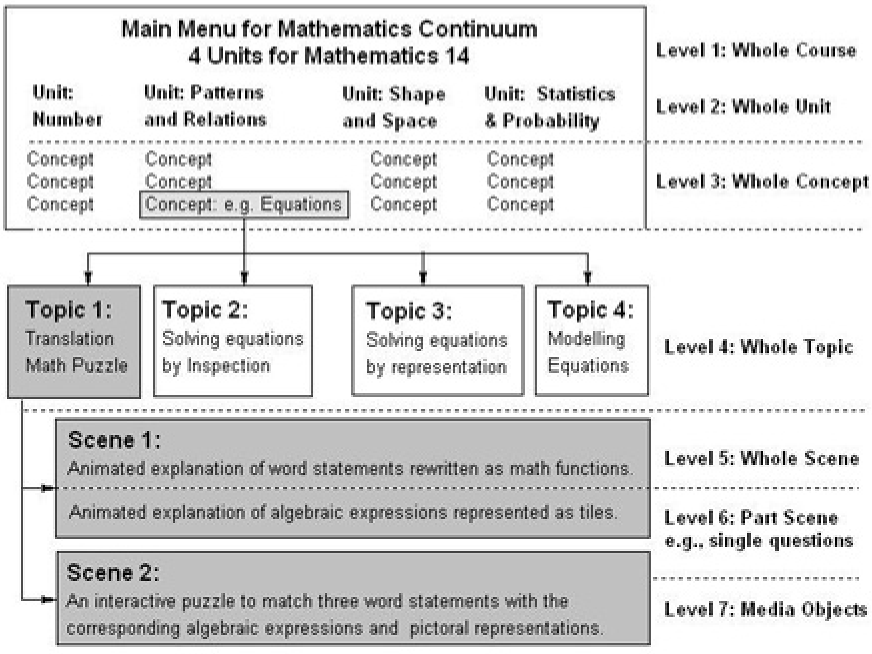

Figure 1: Structure and Seven Levels of Granularity in the LearnAlberta Mathematics Continuum Learning Resource (LearnAlberta, n.d.).

Assumptions and Expectations

To put the initial findings into context, it is useful to begin with a number of assumptions and expectations that existed as the project started. The researchers and teacher / designer had expected to see a balance of linked and embedded learning objects in the Mathematics14 course. Also, to use any learning objects from the LearnAlberta repository in the course, it was anticipated that linking would be used, because, like most learning object repositories, linking was the premise on which the LearnAlberta repository had been designed.

In addition, it was anticipated that there might be some differences in how students accessed linked or embedded learning objects because the LearnAlberta repository requires a login procedure in order to access the learning objects within it.

The first meeting and a detailed examination of the course proved each of these assumptions to be wrong. Contrary to expectations, it was interesting that most of the learning objects within the newly designed Mathematics14 course were embedded, with a ratio of embedded to linked learning objects conservatively estimated as 7:1. Even more puzzling was the fact that learning objects from the LearnAlberta repository were not linked; every one of them had been embedded within the course. Finally, there was no difference in the access to linked or embedded objects from the student perspective. Every object, linked or embedded, was immediately accessible from the course via a single mouse click on a hyperlink. This access was so transparent that the investigators examined the HTML code to differentiate between the linked and embedded objects.

Analysis of the Mathematics 14 course, the Mathematics Continuum Resource and the data from informal discussions and interviews with the teacher / designer generated a number of themes, outlined below.

Issues of Repository Design

When asked for explanation and clarification of these findings, the teacher / designer told a story of the problems she experienced surrounding the use of the learning repository resource and the final resolution. Her story supports the literature and provides some insight into the design and use of learning objects and repositories.

From a content point of view, the teacher / designer thought that the LearnAlberta Mathematics Continuum was an excellent learning resource. She believed that it had been built with practical application in mind. In her opinion, the resource designers had made the effort to help students see how these concepts might be used and this philosophy matched with her own. Moreover, she liked many of the explanations, questions and exercises provided and, based on her years of experience teaching in the classroom, thought that the students would find the games interesting. However, she encountered problems when she wanted to extract various topic and scene segments from the learning resource and link to them as learning objects in the Mathematics 14 Course.

Because of the way the Mathematics Continuum learning resource is designed, linked access to the lower levels of granularity is available only through Level 1, the course level, represented by a top-level main menu. In order to get to a particular topic or scene, students would have to start at the course level, read and follow a series of instructions—sometimes as many as four or five instructions—just to access a single relevant instructional segment.

Linking to a specific scene in the learning resource was further complicated because navigation does not move the user intuitively down through the levels of granularity in order, from 1 to 2 to 3 to 4, etc. When teachers and students click on a concept, they are taken immediately to the first scene of the first topic in the concept. Should teachers or students want to access any later topics or their scenes for a concept, they must then click the topics button in the top left corner of the screen. In terms of navigation, the sequence through the levels is 1, 2, 3, jump to 5, then back to 4. It is not possible to access the third topic of the equations concept, for example, without first going to the first scene of the first topic. As reflected in this explanation, the resource navigation is confusing and requires complicated and non-intuitive instructions.

Concurrent reading and following of instructions was a third obstacle to linking because the instructions and the learning resource were in two different windows. As soon as a student clicked on the Mathematics Continuum window to actually do the instructions, the written directions on the Mathematics 14 course window would disappear.

Linking to the one point of entry at the top level of granularity in the learning resource would result in the need for complicated instructions and frustration with windowing navigation. The teacher / designer felt that this approach would not accommodate the reading weaknesses of the target audience. Also, she wanted to create a direct "path" or "hallway" to the exact learning object so students could not drop into "rooms" along the way and get distracted from their tasks. She was afraid that students would stray to other concepts and topics if tempted by their availability. On this basis, she decided that linking was not an option.

This experience supports Orrill's (2002) suggestions concerning the importance of design and user friendliness of the user management interface. It confirms that the repository design for learning objects can support or hinder innovative use. It also illustrates the importance of learning object design to provide access to learning experiences that are just enough—if you need only part of a course, you can use just the learning objects you need (Chitwood et al., 2002).

Issues of Autonomy, and Self-Containment

As a solution to the "linked" access problem described above, LearnAlberta sent the teacher / designer a CD-ROM with the Mathematics Continuum files on it. This solution was only partially successful, because only some of the topics and scenes would work properly when they were embedded in the Mathematics14, outside of the bigger learning resource framework. As a final fix, LearnAlberta provided a patch that enabled the individual topics and scenes to work autonomously as they were embedded in the course. Even so, the investigators and teacher / designer both noticed limitations and problems with the Mathematics Continuum learning objects when they were removed from the larger learning resource framework and embedded in the Mathematics14 course design. In particular, three limitations interfered with learning and access to it:

- Within the LearnAlberta Mathematics Continuum Learning Resource, students could move back and forth between the various scenes within a topic using navigation bars that were part of the larger resource. Because the navigation framework had been stripped away from the learning objects in the Mathematics14 course, this flexible access to content was removed and the student could only start at the first page of the first scene and move through sequentially.
- In at least one of the Mathematics Continuum learning objects used in the Mathematics14 course there were instructions that referred to the navigation bar. This instruction was confusing and misleading because there was no "Next Topic" button within the Mathematics 14 course interface.
- All learning objects in the LearnAlberta Mathematics Continuum learning resource function well. However, in one question, its counterpart, embedded in the Mathematics14 course, would not evaluate the answer. As a result, it was impossible to proceed to the next question or the next scene. Part of the instruction was missing.

Findings from this teachers' experience support the recommendations of researchers in the literature. Chitwood et al. (2002) suggest that learning objects should be "self-contained". In this case, many of the learning objects within the repository resource were not. As a result, when these learning objects were removed from their original context to a new course context, problems arose with navigational control, inappropriate displays, and missing functionality leading to instructional interruptions. It is quite possible, of course, that the original authors of the Mathematics Continuum resource intended only one “learning object”—the whole course—rather than perceiving it as a collection of learning objects at ever-increasing levels of granularity.

Issues of Technical Support

One issue of significance was the role played by the technical support person at the online school. After the CD-ROM was received, this information technology professional spent a great deal of time looking through the structure of the Mathematics Continuum learning resource in an unsuccessful attempt to find a solution for the teacher / designer’s needs. He gave further support in finding out how the patch worked, organizing resources and teaching the teacher / designer how to use it. This amount of support and time is not reasonable or sustainable; therefore, it is critical that the learning object and repository design support robust and intuitive teacher design.

Issues of Granularity

As the teacher / designer indicated previously, the learning object access problems began because she wanted to access topics and scenes. With this in mind, the investigators used the detailed examination to systematically look at the range of granularity levels from the LearnAlberta Mathematics Continuum resource that the teacher / designer had actually used in the Mathematics 14 course. The investigators found that all of the learning objects used were at Levels 4 (topic) and 5 (scene) with most being at Level 5. No learning objects were found embedded or linked at Levels 1 (course), 2 (unit), 3 (concept), 6 (part scene), or 7 (media object).

During the interview, the teacher / designer offered some of her reflections that help to explain why. First of all, selecting Level 1 (course), Level 2 (unit), or Level 3 (concept) would require that she also accept the instructional organization and structure at that level. Based on years of experience in teaching this course, she indicated that she wanted to use her own organization and structure. The investigators compared the learning resource and the course to explore the details.

The LearnAlberta Mathematics Continuum and the Mathematics14 course both map well to the Alberta Program of Studies, covering the required concepts for Mathematics 14, but the organization of each was quite different at Levels 1 and 2. The four original units in the Mathematics Continuum Menu became five units in the Mathematics 14 course (see Table 1).

Table 1: Partial Comparison between LearnAlberta Mathematics Continuum Learning Resource and the Mathematics 14 Course (Granularity Levels 2 & 3).

LearnAlberta Mathematics Continuum (4 Units)	Mathematics14 course (5 Units)
Unit 1: Numbers Concept: Fractions Add & Subtract Concept: Equivalent Fractions Concept: Fractions Multiply & Divide Concept: Integers Add and Subtract Concept: Integers Multiply & Divide Concept: Order of Operations Concept: Percent Concept: Rates and Ratios	Unit 1: Number Concept: Numbers Overview Concept: Order of Operations Concept: Integers Concept: Adding Integers Concept: Subtracting Integers Concept: Multiplying & Dividing Integers Concept: Using Integers Concept: Integers Conclusion Project: Wallflower Project Concept: Decimals Introduction Concept: Rounding Decimals Concept: Adding & Subtracting Decimals Concept: Multiplying Decimals Concept: Dividing Decimals Concept: Unit 1 Conclusion Test: Unit 1 Test
Unit 2: Patterns and Relations	Unit 2: Patterns and Equations
Unit 3: Shape and Space	Unit 3: Fractions, Ratios, & Percent
Unit 4: Statistics and Probability	Unit 4: Measurement
	Unit 5: Geometry

As indicated in Table 1, it became apparent that the teacher / designer's organizational, structural and sequential re-arrangements in the learning resource were not constrained to units at Level 2. The comparison also revealed variations at Level 3, concepts. Even within similar units (e.g., Number) there were significant differences.

- The same concepts (e.g., Order of Operations) are presented in a different sequence;
- The Mathematics14 course organizes the concepts into smaller lessons. For example, "adding" and "subtracting" integers are combined in the LearnAlberta Mathematics Continuum resource; they are separate lessons in the Mathematics14 course;
- Some concepts, e.g., fractions, are taught in different units;
- The Mathematics14 course has additional learning objects, over and above the LearnAlberta Mathematics Continuum learning resource.

The decisions made with respect to levels of granularity centered primarily on flexibility and choice for the teacher—the choice to re-organize, re-arrange, add, or delete segments of the whole. When asked if she would ever link or embed a whole course as a learning object, the reply was an emphatic

Never! … Never… the same way that every learner in my classroom isn't going to attach themselves to what I've done in the same way as the guy next door, I need to be able to take that and make it my own so that I can interpret it for what I'm doing in the classroom.

However, later in the discussion, when it was suggested that all teachers might feel this way, the teacher / designer argued that following a pre-determined course in a textbook or learning resource might well be attractive to some teachers, especially for novices or for those with weak mathematics skills. Her argument brings forward a dimension of choice over and above "which" learning objects—i.e., it is possible that individual teachers / designers will need different choices in granularity level.

A second comment provoked yet another thought concerning learning objects, granularity and choice. When talking about reusability at a course level, the teacher / designer said "Even if I could take my course … and put it on Alberta Learning, I wouldn't use it that way in a face to face classroom." It would appear that flexibility of choice in mixing and matching learning objects moves beyond accommodating different teachers; it may, in fact, be critical for accommodating change requirements for a single teacher across different circumstances, enabling them to adapt their instruction to different delivery modes and students.

Issues around Linking and Embedding

When many of the above issues had been aired, the investigators were still curious about what the teacher / designer's preferences would be for linking and embedding (a) if establishing the link from any level of granularity in the learning resource was easy to do, and (b) if the resulting look and feel of linked objects was as transparent for the students as the access to embedded learning objects—i.e., a single hyperlink to the learning object. Her answer was "Oh, embed … because then it's in my course. I've got it. It doesn't matter what the webmaster at that site does … changes the link … already, there's two later on in unit 5 that are dead." This concern about preservation is noted in the literature. Calverley (2006), in particular, looks at maximizing the useful lifetime of learning objects through design considerations for the repository. Her suggestions may well promote repository and learning object usability. For example, a repository that immediately notifies the user if a resource no longer exists will be helpful for those who wish to link to objects, especially if the notification includes alternative access; the choice to re-export updated objects may well be of benefit to those who embed learning objects.

At the beginning of this study, an important research question was how students used linked and embedded learning objects in the Mathematics14 course. Unfortunately, in terms of course content, the WEB-CT course management system only tracked page access. It was impossible to tell what linked or embedded objects on the page had been accessed and for how long. Further research into the actual practices of students using this course could provide valuable insights into subsequent course, learning object, and repository design.

Issues around Process and Pedagogy

The richness of the Mathematics14 course helps to highlight the pedagogical role that teachers play in resource design. As shown in Figure 2, the Mathematics 14 course is a rich collection of linked and embedded learning objects collected from a wide variety of sources—e.g., the textbook, contextualized examples, the LearnAlberta Mathematics Continuum learning objects, external web-based learning objects, and teacher-made learning objects. Instructional expertise is evident in the web-based instructional course framework or wrap-around.

There were some obstacles to overcome before teaching expertise could be employed in the construction of the course. First, the teacher / designer mapped the LearnAlberta Mathematics Continuum to the Alberta Mathematics 14 curriculum to ensure compliance. For each learning outcome, the teacher / designer browsed the learning resource to find out what was available and to assess how useful it would be for her purposes. All in all, according to the teacher / designer “it still took a fair bit of drilling.” There was no search functionality within the learning object. It was impossible to expand each concept to see which bullets (topics) were associated with it. Often, names and labels (e.g., “Space and Relationships”) did not mean anything to her and were inconsistent with either the Program of Studies or the textbook. There was no way of telling what the content might be for a particular concept, topic, or scene until she went into it. Some topic descriptions gave some idea of the content but many did not. In short, with the current repository and learning object design “It takes a lot of lead time … a long time to find out the details of what is actually in the electronic resource and then to decide how you are going to use it in your own classroom” (Teacher / Designer, interview).

Wiley (2002) cautions that learning objects must be combined in such a way that quality meaningful learning can be supported. “Combination” appears to be only one step in the process of constructing quality learning experiences and, in this case, repository design was key to helping and hindering this effort.

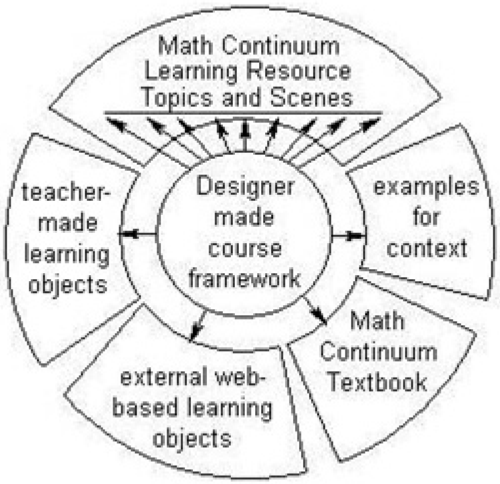

Figure 2. Mathematics 14 Lesson Structure.

Conclusion

While the themes above may not be generaliseable to a larger population, findings related to the first two research questions do result in context-specific examples that support many of the suggestions already in the literature and raise a number of novel ideas for further consideration.

One such idea questions the sufficiency of instruction within a learning object. In such a learning object, the instruction usually focuses primarily on content, resulting in a “one size fits all” solution for a broadly defined audience (e.g., a grade). This study brings forward a critical aspect of pedagogy—that of teacher expertise in adapting instruction for individual and personalized learning. As the teacher / designer in this study carefully selected, collected and assembled the elements that would promote and scaffold learning for her current class, she was already anticipating that a different aggregation of elements would be needed for a different audience in a different situation.

A second insight builds on the notions of size, modularity and the construction of learning objects. In a larger learning object such as the Mathematics Continuum Resource that encompasses a whole course, unit, etc., it would appear to be difficult to predict which level of granularity and which “pieces” within that level that a teacher might want to use for any particular instructional situation. In this case, conceptualizing and building the larger learning object as an ever-increasing aggregation of smaller, self-contained and modular learning objects might provide affordances for selective access to any segment(s) at any level(s) of granularity. For linking, it might then be possible to associate every segment with a single URL, allowing direct access to the exact segment(s) without having to navigate the structural hierarchy. For embedding, the hierarchy of independent units may afford ways of intuitively "packaging" selected modules in a level for download. These randomly-accessible modules would also facilitate teacher "browsing" in the search for relevant materials. Based on the results of this study, we suggest that the greater the degree of granularity of the learning object itself, the greater the potential of it being adapted, reconstructed, and reconfigured.

The "teacher browsing" part of the process leads us to a third insight around searchability and visibility. The results of the current study suggest that searchability within a learning object as well as for a learning object in a repository would facilitate teacher use of it. As a complement to searchability, we suggest that efforts toward increasing the visibility of internal learning object structure and content (with thumbnails and teacher-relevant annotations, for example) will help a teacher to find those pieces which are relevant to a particular purpose.

Thus, we add "granularity", "searchability" and "visibility" to the "ilities" of learning objects (South & Monson, 2002, p. 224):

- Durability
- Interoperability
- Accessibility
- Reusability
- Discoverability
- Extensibility
- Affordability
- Manageability

We conclude that repository and learning object design are integrally linked to pedagogical use. Have teachers been left out of the design of learning objects and repositories? As the teacher / designer indicated.

It's not that I need somebody to suggest to me what to do with that activity, because that's what I do well .... But let me know what it is … and let me change the questions that you've got built in here .…Let me make it work for what I'm already doing.

If this teacher / designer is representative, it might suggest that teachers have never had to "shift their emphasis from metadata and standards to learning and the actual practices in the field." They have always been learner-centered and are now quietly waiting for the learning object and repository designers to make contents accessible for learning and actual practice.

Implications of this research suggest that future studies must shift away from the "low hanging fruit" of standards and metadata. These studies must respect teacher-knowledge, needs, and experience and include the working professionals in the design of relevant repository structures that allow embedding, re-purposing, and content sharing at various levels of usage. We believe that while the teacher reflected in this study was special, in terms of support, position and access, other teachers, specifically new teachers who have been trained to use digital media in their preservice experiences, will not only want this but they will simply expect it.

Therefore next steps for subsequent studies might include:

- Exploring the ways in which novice teachers might consider the use and development of learning objects,
- Exploring the ways in which the content selected for generic learning object development is determined,
- Exploring the ways in which teachers might more easily be encouraged to re-purpose existing learning objects,
- Exploring the ways in which learning object developments might be encourage to design them in multiple levels of granularity, assuming that end users will in fact modify them and share them, and
- Exploring the ways in which learning object developments might be encourage to design them to support and encourage modification and site specific adaptation.

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Appendix A
Initial Interview Questions

Note that other questions arose based on the answers to the following:

- Describe the course you are designing? Who are the learners for this course?
- How are you using learning objects in your course? Why?

- How did you use learning objects that were available in local environments? How did you use learning objects from those that are linked from a central repository? How did you choose whether to link or embed the object?

Final Interview Questions

Note that other questions arose based on the answers to the following:

- How did you go about designing the course? What are the steps you took? How did you decide on the learning object(s) you selected?
- How did the design of the learning object repository affect the design of your course? How did students use the learning objects?
- What would be your preference if linking and embedding objects were equally easy to implement and equally intuitive for student use?
- Do you think that embedding vs. linking learning objects affected student use of / access to the learning object? How?
- Would you ever link or embed a “whole course” learning object?

Do you think that other teachers would find your course useful if you were to put it in the repository?

ISSN: 1499-6685