Curator: Learning Object Construction Matrix

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Abstract — *The diversity of skills and knowledge necessary for the success of today's learners has accentuated the need for flexible and targeted instruction. Proponents of "learning anywhere, anytime" envision learning objects as integral to the development of future versions of electronic delivery systems. The goal is to make these materials and instructional resources available in a more predictable and standard fashion. The key is not in how the data is stored but in how an educator can locate the most appropriate object for a lesson. Each digital object may be indexed according to various characteristics, but currently these coding schemes are typically proprietary and of limited value. This paper describes the Learning Object Construction Matrix with rationale and introduces* `Curator`*, a prototype application developed to support the indexing of learning objects according to this matrix.*

Index Terms — learning objects, learning repositories, Curator, web–based education.

Introduction

The ever-changing demands placed on our work force and military personnel require a diverse and constantly evolving mix of skills and knowledge. The need to keep pace with and be successful in meeting these demands has placed an educational focus on widely available, flexible, and targeted instruction. Learning objects are seen as integral to the development of future versions of electronic educational delivery systems by proponents of this type of "learning anywhere, anytime." Such people envision global electronic libraries of shared learning objects, not unlike the current public library system found in the United States. The marvelous promise of this approach is the possibility that such libraries could compile vast databases of digital resources catalogued by a learning content management system.

Suppose, for example, that a college professor creates an electronic slide show illustrating various sorting methods in computer science. This presentation could be made publicly available and referenced in a database of Computer Science topics so that a high school teacher could then access it for his or her own classroom use. Digital development and delivery provides reusability of these types of learning objects, which theoretically could be utilized for targeted and customized instruction on demand.

Attempts to realize this potential have encountered major problems stemming from an inability to 1) identify, 2) locate, and 3) situate within an appropriate learning experience the most suitable learning objects. In this paper, we give a brief overview of learning objects and the current state of electronic portals to them. We then present a new model for the identification, classification, and retrieval of electronic learning objects.

Learning Objects

Actually, there is a lack of common vocabulary and definition with respect to learning objects. As Mortimer [1] observes, "[N]o single learning object definition exists within the e-learning industry.... [T]here seem to be as many definitions as there are people to ask." One very popular view of learning objects is that of "any digital resource that can be reused to support learning" [2, 3]. This view of learning objects obscures the fact that the utilization of materials which support learning is a very old practice.

Learning objects are not a recent innovation. From the first grade teacher who has a chart of the alphabet above the chalkboard in his or her classroom, to the social studies teacher showing a video about World War II, shareable educational materials have been a fixture in classrooms for decades. However, the ways in which teachers create and share learning objects is changing. Hence, a different perspective sees learning objects as any element which supports and reinforces learning. Educational materials, instructional aids, and learning resources are all examples under this broader view in which teachers, instructors, and professors create learning objects every day. For example, as Downes [4] notes, "[T]here are thousands of colleges and universities [teaching] a course in introductory trigonometry. Each such trigonometry course [describes] the sine wave function [which is] more or less the same as other institutions'. [If these courses are put online, the] result will be thousands of similar descriptions of sine wave functions available online."

The cost to create these materials is expensive in terms of both time and money. Producing a high quality, fully interactive introductory lesson on sine waves

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might cost, perhaps, around $1,000 [4]. A tremendous amount of redundancy results from individual professors producing learning materials for one lesson in one course, when there are hundreds of them around the world doing so. Therefore, the goal is not to produce hundreds or thousands of similar lesson components, but to provide shared access to educational material. Typically, educators have used textbooks and other published material to achieve this goal. One problem with these types of learning materials is that they become stale and are difficult to modify. Further, they may be hard to find and impossible to access remotely.

The Internet has become a tremendous asset to educators for locating instructional materials anytime and anywhere. One of our goals is to make online instructional resources available in a more predictable and standard fashion.

Learning Object Repositories

Digital libraries or repositories that serve as electronic portals of learning objects are beginning to appear online. Two examples are Canada's SchoolNet [5] and the Multimedia Educational Resource for Learning and Online Teaching (Merlot) [6] in the United States. Merlot is an online resource that links learning materials together with peer reviews and assignments.

Storing and providing access to educational objects in a database is nothing new. The key is not in how the data is stored, but that as a developer one can locate the most appropriate object for a lesson. Therefore, each object is tagged with a content model much like the labeling of a can of soup. As Mortimer [1] points out, "Basically, the content model defines a set of metatags, or coded statements, for learning content. When you employ metatags, you mark the content with metadata, or information about itself, such as language, keywords, or interactivity level."

Currently, these coding schemes are typically proprietary and of limited value. As Downes [4] notes, "Educators attempting to use Merlot's resources... still experience frustration... [and] must still spend quite a bit of time browsing for materials. Moreover, there appears to be no resource metadata and the search mechanism provided on the Merlot site is no better than standard web search engines."

A major problem in developing learning object systems is that there is little guidance on how to match the appropriate educational delivery model with the content. Current metatag models do not provide enough useful information to educators and instructional designers in order to comprehend how a specific learning object fits into a particular lesson structure.

Consider the prior example of the introductory course in trigonometry. It is not sufficient to simply identify a learning object dealing with the sine wave function. Much more detail about the content is required, such as the level of the intended student and the type of delivery model used. Clearly, from an instructional design perspective, a better understanding of the nature of the learning object, and of educational paradigms, is essential. Consequently, while developers, instructional designers, and content experts who create and utilize learning objects have been concerned with locating a specific learning object, they must also contend with the key issue of understanding how that object would fit into and sequence within a lesson delivery system. A targeted system for classifying and identifying learning objects is desperately needed.

The `MENTOR` Project

The `Mentor` Project [2] is being developed to explore the issues of utilizing learning objects and incorporating educational theory into instructional technology in an open source environment. When completed, it will be a fusion of instructional design and a course authoring, management, and delivery system, with the ability to create and manage a learning object repository. The project's three main components, `Curator`, `Pathfinder`, and `Mentor`, reflect the three basic areas of endeavor required to develop and maintain electronic lessons. These broad divisions are creating, managing, and maintaining:

1. the repository: a collection of learning objects,
2. the lessons: a collection of lesson sequence maps, and
3. the delivery: the interaction between various lessons and learners

These tasks interact as shown in the figure below.

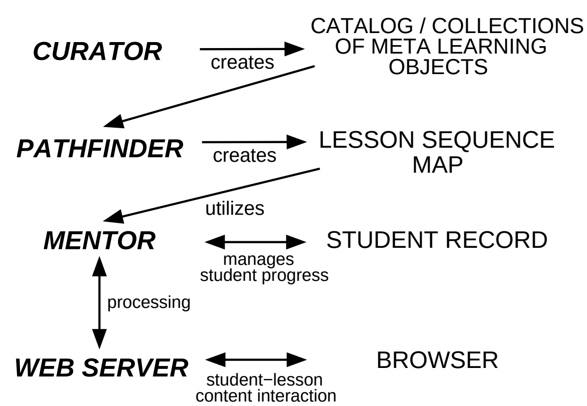

FIGURE 1. The `Mentor` project

A learning object containing course content may be viewed simply as data. Tags contain technical and instructional details for learning objects, information indicating its content area, level of complexity, delivery requirements, and so forth. Thus, tags are *metadata*. The files which describe the structure and meaning of tag content are *meta–metadata*, and were implemented, quite naturally, as `XML Document Type Definitions`. A tagged learning object is called a *meta–learning object*, to distinguish it from untagged digital resources.

Conceptually, within a learning space an instructional designer mediates between lesson content, learning objects, and students. To facilitate this task, `Curator` manages a `catalog` of learning object `collections` with the ability to create, manage, and maintain meta–learning objects.

`Pathfinder` may be used to create and modify sequenced lessons from meta–learning objects. It utilizes the catalogs, collections, and tags created by `Curator` to build a `lesson sequence map` or set of pathways from a *source* node to a *target* node, which represent the initial and *learned* or exit states of the lesson. Such a map is similar in function and appearance to a finite state machine. Meta–learning objects are incorporated into these node sequences, which are used to guide the learner through a series of learning experiences aimed at a specific outcome.

`Mentor` will then mediate between the learner and the lesson(s) created by `Pathfinder`. When implemented, `Mentor` will track student progress and outcomes in order to provide instant feedback and guidance to students and to supply the instructor with statistics and other data related to the students and particular lesson sequence maps.

It is intended that the various components of the `Mentor` Project will be integrated fully, allowing an instructional designer to catalog and maintain a collection of digital resources, create lesson sequence maps from these meta–learning objects, mediate between the maps and students, and track learner outcomes.

Instructional Design Issues

Instructional systems are concerned with three major components: learner level, content type, and delivery technique. To design effective instruction, the lesson author must understand for whom the instruction is intended, what deficiency exists in terms of skill or knowledge, and the most appropriate or effective delivery model necessary to achieve performance outcomes. By providing this type of information, a designer is better equipped to make appropriate decisions in lesson design.

During the development of `Pathfinder` for the `Mentor` Project [2], it was discovered that the initial learning object tags did not provide adequate data for an instructional designer to properly insert learning objects into effective and appropriate learning sequences. In fact, it was determined that data identifying the supported learning outcome, content, and delivery types was needed.

Using a traditional content taxonomy of educational objectives provided an appropriate classification system for identifying learning outcomes ranging from simple factual information to higher conceptual learning [7]. In addition, understanding how this specific content should be delivered to maximize results is crucial information necessary to integrate the learning object within an instructional sequence. Thus, a well-known taxonomy of well-understood delivery models based on underlying theoretical framework designed to foster a particular type of learning appropriate for the type of learner and content [8] was chosen here as well. Finally, a requirement was included that the lesson designer understand the learner for whom this object was targeted.

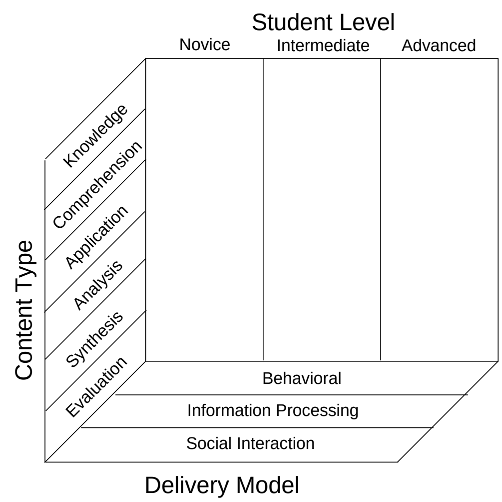

FIGURE 2. Learning Object Construction Matrix

In practice, there is a high level of interdependence between the elements of learner, content, and delivery. For example, the level of content will change if the learner is a novice. Further, the type of delivery model chosen is dependent upon the learner's level, as well as the type of content being presented. Therefore, in order to better evaluate learning objects, the Learning Object Construction Matrix (LOCM) [9] was developed.

Learning Object Construction Matrix

The LOCM, shown in Figure 2 above, was developed as a learning space that revolves around three major axes. The Student Level identifies the initial state of the learner (novice to expert) relative to the content. The Content Type axis defines the intended learning outcome required by the learner; it ranges from simple factual information to the higher level skills of synthesis and evaluation. Finally, the Delivery Model element defines the delivery technique the learning object uses – from simple drill and practice to small group discussion – in order to attain the intended learning outcome.

The LOCM provides a graphic representation of the interdependence of these three instruction elements. Given this framework showing the relationship between learner, content, and delivery, a content developer can more easily identify a learning object by situating it within the LOCM space.

Improving the DTD

Using the matrix as a guide, the working lesson content Document Type Definition (DTD) for a learning object was revised. This DTD provides the acceptable syntax and semantics of learning object tags which are used to interface with `Pathfinder` [2].

Given the design of the LOCM, we wanted to create an application to facilitate the tagging of learning objects. On the one hand, it would provide content developers with an opportunity to tag learning objects in a way that makes sense to instructional developers. On the other hand, educators could also make use of the object. The goal was to provide a meta-meta tagging application that could be used within current learning object repositories as well as to tag new content as it is developed.

```
<?xml encoding="US-ASCII"?>

<!ELEMENT catalog (name,(collection)*)>
<!ELEMENT collection (name,(items)*)>
<!ELEMENT items (artifact)*>
<!ELEMENT artifact (name,location,note,learner,
                    type,model,delivery)*>
<!ELEMENT name (#PCDATA)>
<!ELEMENT location (#PCDATA)>
<!ELEMENT note (#PCDATA)>
<!ELEMENT learner (#PCDATA)>
<!ELEMENT type (#PCDATA)>
<!ELEMENT model (#PCDATA)>
<!ELEMENT delivery (#PCDATA)>
```

FIGURE 3. `Curator` DTD

The DTD emerged from the LOCM by considering the general needs of content developers. Museums and institutions, for example, may create learning objects that have only a general connection to each other. Consequently, the highest level of interconnection presented could likely be the catalog containing different collections. To illustrate, in an aquarium there may be different types of sea life ranging from fish to mammals. Each of the animal species are related by more than the fact that they co-habit an aquarium, but may simply be listed in a brochure by what species each tank contains. To an educator, however, it is important to provide a higher level of categorization in order to facilitate locating and identifying relevant learning objects. Within a collection of learning objects, then, we identify each object with a name and an artifact which provides the meta data necessary for the integration of the object into an appropriate learning sequence. Based on these concepts, the DTD shown in Figure 3 was developed.

The output from a content developer, along with this DTD, is given to the `Curator` software. The resulting output is formatted in XML, and for our previous example, looks as follows:

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE catalog SYSTEM "curator.dtd">
<catalog>
 <name>Sea Critters</name>
 <collection>
  <name>Fish</name>
  <archive>
   <name>tuna</name>
   <location>claytablet</location>
   <comment>blue fish</comment>
   <learner>Intermediate</learner>
   <type>Comprehensive</type>
   <model>Behavioral</model>
   <delivery>Discussion</delivery>
  </archive>
  <archive>
   <name>salmon</name>
   <location>mbari</location>
   <comment>red fish</comment>
   <learner>Advanced</learner>
   <type>Analysis</type>
   <model>Behavioral</model>
   <delivery>Tutorial</delivery>
  </archive>
 </collection>
</catalog>
```

FIGURE 4. `Curator` OUTPUT IN XML

The DTD defines the structure and meaning of the XML file, which in turn describes the learning object and its attributes. Note that each item's name is also the name of the associated artifact. This helps in organizing learning objects and their artifacts.

Curator

The `Curator` software, in keeping with the larger `Mentor` Project, was implemented using Java 1.3.1 and XML. The goal was to render the LOCM as an application that content developers would find easy to learn.

One assumption made which impacted the interface design was that users of `Curator` would have an understanding of the educational and instructional goals that a particular learning object would satisfy. For example, content providers for libraries, museums, and so forth, might focus on developing learning objects. By this assumption, the `Curator` user would be the educational outreach director and not the technical developer of the learning object. This person would likely be in charge of satisfying the educational mission of the institution. With this in mind, `Curator` was designed with an intuitive interface that should not only be easy to learn and use, but functionally translates the LOCM. Thus, the opening screen has only three menu options: Catalog, Collection, and `Curator`.

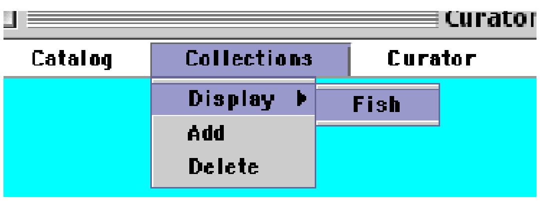

FIGURE 5. Cascading submenu

The Catalog menu item allows the user to create a new catalog or open one which was previously developed. Notice that Collection is disabled on start-up. If the user chooses to begin a new catalog, `Curator` pops up a dialog box that requests a name. This name will serve as the file and document name. Once the user has loaded or created a new catalog, the collection menu becomes active and manages each of the collections in the catalog.

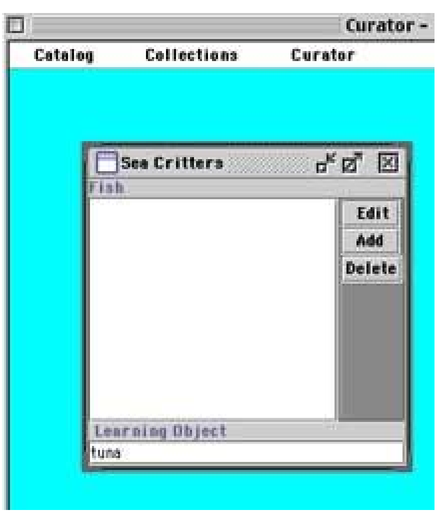

FIGURE 6. Collection Window

The Collection menu allows the user to display, add, or delete collections in the catalog. The display lists each of the available collections within the catalog in a cascading menu consisting of registered collections (Figure 5). In addition, the display sub-menu allows the user to select an item in order to view the specific collection window.

If the user is working on a new catalog, then the display sub-menu is blank. Adding a collection to the catalog first requires the user to enter the name of the collection, then a pop-up window appears which allows the user to manage the new collection. Notice the window is labeled with the catalog and the specific collection name.

The collection window, as shown in Figure 6, is designed to manage and organize the various learning objects within the specific collection. The window lists each of the learning objects within the collection and provides mechanisms for list management. Each list item is defined by the LOCM.

To add a new object to the collection, the user first enters its name in the field located in the bottom portion of the screen. Then the user clicks "add" which displays the learning artifact window, shown in Figure 7.

FIGURE 7. Artifact Window

The learning object artifact window models the LOCM and is composed of three major sections. The Title Information portion identifies the name of the object and its location. A field is also furnished for the content developer to enter narrative information concerning the object. This provides another perspective that may help lesson developers select and integrate the learning object into a lesson sequence.

The Target Level section identifies the level toward which the learning object is directed: novice, intermediate, or advanced. If utilized, a custom button causes a pop-up dialog box to appear in which the content developer can more precisely identify the intended level of the learner. For example, if a particular learning object requires a level of expertise that falls somewhere between a novice and an intermediate learner, the content developer can provide that level of specificity. Rather than attempting to anticipate all the various levels of learner preparation, we simply made provision for a custom label.

The Classification area is divided into two subsections: Content Type and Delivery Models. Content Type reflects the taxonomy of learning outcomes and is used to identify the type of expected outcomes this particular learning object is intended to satisfy. Delivery Models include Behavioral, Cognitive, Social, and Custom, with subcategories such as Tutorial and Drill & Practice also provided.

Typically, reusable learning objects are described as fragments, sections, or parts of a larger learning context. As was noted earlier, the use of a sine wave function is common to all trigonometry courses. Therefore, to facilitate the tagging of learning objects, it was assumed that in general most objects can be identified using exactly one of the learning outcomes listed in the taxonomy. Consequently, the user is provided with radio buttons that are mutually exclusive. However, since at times a specific learning object might blur the distinction between outcomes, a custom button is one of the choices. It allows the developer to categorize the learning object under consideration as they see fit.

The final area within the classification section is concerned with the delivery model for the learning object. This posed the greatest challenge in developing the interface. The goal was to maintain the coherence of the window without overwhelming the user. The possibility of opening multiple windows was considered, but rejected on the grounds that we did not want the user to be forced to navigate between them. It is likely that users will already have several windows open at this stage as they review various objects.

The assumption was made that the user is aware of and understands instructional delivery methods and learner needs. This allowed the creation of a tab view labeled with the names of the four major teaching model families (behavioral, information processing, social interaction, and personal source), as described by Joyce and Weil [8]. Once the user selects the tab which they have identified as the desired delivery model for the learning object, they are presented with particular delivery techniques from which to choose that are typical for that family.

Again, the assumption was made that delivery techniques are discrete and exactly one of them is applicable to any given learning object, which presupposes a mutually exclusive set of delivery choices. However, it was also recognized that flexibility is very important, so there is a custom area that allows the content developer to define the delivery in nonstandard terms.

Summary

A flexible, robust, and non-proprietary yet standard means for identifying, classifying, and retrieving learning objects is sorely needed in order to meet the growing demand for targeted and customized instruction on demand. Along with content and technical details, instructional design information such as target audience preparation level(s), learner outcome(s), and delivery method(s) must be included in the design of learning objects and their associated information or tags. A new model has been presented for learning object metatags and tags which incorporates these properties, and have described the implementation of this model in `Curator`, one component of the `Mentor` Project.

The goal of `Curator` was not to support a particular learning theory or delivery philosophy, but to allow the greatest flexibility possible in identifying and classifying electronic learning objects. It adheres to long established and well tested educational theory, and allows the tag creator to match the learning object with the best description of its instructional use and preferred delivery method, independent of any specific or designated educational philosophy.

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