

# Designing Reusable Object-based Lesson for Mathematics

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## Abstract

The production of multimedia learning content is an extremely expensive task in terms of time and cost. Hence, optimizing production by exploiting the reusability of multimedia content is mandatory. Reusability of instructional content is a central issue in e-learning to facilitate the usage and manipulation of the highly distributed and heterogeneous collection of learning sources. This paper describes a study on the design of data driven reusable object-based lesson for first year university mathematics as a supplement to the traditional lecture and textbook. Some of the essential components of this study are the learning object instructional properties and design principles, definition of object-based lesson model, and also the principles behind the implementation of object-based lesson that meet the learners and instructional design requirements.

## Keywords

Object-based lesson; Distance Learning; Mathematics; Learning Objects; Reusability.

## 1. Introduction

Since the Internet has come into wide spread use, the education community has viewed it as an opportunity to reach new models for teaching pedagogy that have been out of reach within the traditional educational environment. Throughout the world, people are developing educational multimedia materials. These instructional materials are being used in classroom demonstration, hand-on laboratories, self-directed work outside of class and distance online learning. Most of the instructional designers used Bates's model to develop instructional contents where a complete course is the smallest independent level of learning unit. Courses developed along this model take much effort and incur high costs because it is created from scratch and usually this course material is applied to a limited number of students (Bates, 2000). Furthermore, instructional designers have huge expenses to keep instructional contents up to date. This problem occurs especially in the areas where knowledge changes rapidly, such as in IT domain.

Currently a new concept for e-learning is the object-based learning. This approach is a new way of thinking about instructional content. The idea is to decompose existing course material into so-called "Learning Objects" (LTSC, 2000). Traditionally, content comes in a several hours chunk

called a course. Learning objects are self-contained, modular pieces of course material appropriately annotated with metadata. They may be combined to form larger educational interactions. The goal is to develop an open architecture for online learning that will allow teaching to be centered around the needs and interests of the learner, enabling learning to occur anytime, anyplace and to allow for greater customization and flexibility of the learning environment.

Today the learning object has emerged as instructional technology's new paradigm. This idea has gained such broad acceptance that the IEEE has formed the Learning Technology Standards Committee to pursue the creation of common standards for the description, interchange, and management of learning objects (LTSC, 2000). As time passes, eventually object-based technologies are replacing classical instructional design approaches. This leads to reuse, and reuse leads to faster development and higher quality instructional contents. In addition, as object-based systems are easier to adopt and easier to scale, assembling reusable learning objects can create large instructional materials.

This paper describes a study on the design of data-driven reusable object-based lessons that meet the learners and instructional design requirements because “good instructional design is more important than the specific technology” (Davie & Inskip, 1992). First some background and key aspects of learning objects design principles and instructional properties are given. This is followed by an explanation of how reusable object-based lesson models with sound instructional design are defined. Several examples are then provided to illustrate how to implement the reusable object-based lesson.

## **2. Reusable Learning Objects**

For many years, learning objects have been widely discussed in the open literature in many different perspectives. In fact many terms are used in the literature and industry, besides “learning objects” by IEEE Learning Technology Standard Committee (LTSC, 2000). Other terms that imply the general intention to take an object-oriented approach to online learning are “knowledge objects” (Merrill, Li, & Jones, 1991), “pedagogical documents” (ARIADNE, 1999), “online learning materials” (MERLOT, 2000), and “educational software components” (ESCOT, 2001).

The Learning Technology Standards Committee chose the term "Learning Objects" to describe these small instructional components and provided a working definition:

" any entity, digital or non digital, which can be used, reused or referenced during technology supported learning. Examples of technology-supported learning include computer-based training systems, interactive learning environments, intelligent computer-aided instruction systems, distance learning systems, and collaborative learning environments. Examples of learning objects include multimedia content, instructional content, learning objectives, instructional software and software tools, and persons, organizations, or events referenced during technology supported learning " (LOM,2000).

Currently, we will see more and more instructional content developed specifically to be deployed as learning objects in multiple learning contexts due to its potential for reusability, interoperability, discoverability, and manageability (Singh, 2000). There are two approaches to design the reusable

object-based lesson. First, by searching and using the existing instructional materials which can be considered as learning objects from the online learning sources, such as the Internet. Secondly, design or convert the instructional materials into object forms. The key underlying principle of creating object-based lessons from learning objects is that sound instructional design practices must be followed. A standardized principles for learning objects design and instructional properties are necessary to aid in the design process so that instructional contents can eventually be used for facilitating intended learning outcomes and reused within and between different learning contexts at an appropriate level of granularity. An instructional content is only considered as learning object if with the following instructional properties:

(a) Learning objects must be instructional objects

A learning object is an instructional object, not just a piece of informational object. It must provide deliberate instruction at a appropriated level with meaningful interaction, in order to retain skills or key concepts by the learner. Often if the object is an informational object, the intention is just to inform, but if the object is a learning object, then it will provide an environment that is much more conducive to facilitate learning and reinforce the recognition of skills or key concepts.

(b) Learning objects must be relatively small

The learning object for instructional contents should focus on a single learning objective, so that it will be relatively small, discrete or unit of knowledge to support flexible, individualized learning (Longmire, 2000). It is important to note that simply being physically small does not qualify as a learning object. To equate a learning object, information or content must be small and focused. If each learning object is based upon a single objective, and the granularity is small enough, then each learning object will be "appropriately" small.

(c) Learning objects must be extractable or stand-alone

A learning object must be self-sufficient to provide instructional information in the form of modular units and no relies on previously learned information, references or examples in order to clearly provide instruction on a concept (Quinn & Hobbs, 2000). The lack of self-sufficiency is one of the reasons why most existing educational materials do not qualify as learning objects.

(d) Learning objects must be usable on a standard platform.

Learning objects should work in a variety of standard Web platforms. It should require only web browsers and some common plug-ins which are available free for download from Internet for viewing objects created with Flash, Director, Shockwave, Java Applet, and Java Scripts. No prior software component installations should require other than those provided by the web browsers and operating systems.

(e) Learning object must be tagged and searchable.

In order for learning objects to be used, and reused widely to meet real-world performance criteria, they must be shared, accessible and discoverable by others across learning environments. They must be labeled as to what they contain, what they teach, and what requirements exist for using them so that users understand what a learning object is about without ever seeing them (Downes, 2000; Quinn & Hobbs, 2000). Currently there are initiatives for building the metadata schema that will allow for the universal sharing of learning objects. Examples of existing metadata standard which can be used are Dublin Core Meta-data (Dublin Core, 1999) and IMS Metadata (IMS, 2000).

### 3. Object-based Lesson Model

According to Thiagarajan, S. (1993) an effective instructional lesson irrespective of subject matter should have these three components: Presentation, Activities, and Feedback. We should not ignore any of these three components in all instructional design. From a pedagogical perspective, each object-based lesson is composed of two major components: Learning Strategies Component, and Learning Content Component. The Learning Strategies Component consists of three elements: Learning Objective, Introduction, and Summary which, must be designed and integrated into every lesson in order to create a complete instructional experience. The Learning Content Component also consists of three elements: Content, Activity, and Assessment, which are the learning objects used by the learners to achieve the learning objective. This lesson plan structure like any traditional learning lesson plan, is to ensure that instructional designers are aware of all the factors and elements governing a lesson.

By adopting mathematical sets, it can be suggested that the structural components of object-based lessons are:

$$\begin{aligned}\text{Subject } i &= \{\text{Lesson } i\} \text{ for } \forall i \in \mathbb{N}, \text{ where } \mathbb{N} = [1, 2, 3, \dots] \\ \text{Lesson } i &= \{\text{Topic } i\} \text{ for } \forall i \in \mathbb{N}, \text{ where } \mathbb{N} = [1, 2, 3, \dots] \\ \text{Topic } i &= \{\text{Learning Content } i, \text{ Learning Strategy } i\} \text{ for } \forall i \in \mathbb{N}, \text{ where } \mathbb{N} = [1, \\ & \quad 2, 3, \dots] \\ \text{Learning Content } i &= \{\text{Content Page } i, \text{ Activity Page } i, \text{ Assessment Page } i\} \text{ for } \\ & \quad \forall i \in \mathbb{N}, \text{ where } \mathbb{N} = [1, 2, 3, \dots] \\ \text{Learning Strategy } i &= \{\text{Learning Objective } i, \text{ Introduction } i, \text{ Summary } i\} \text{ for } \\ & \quad \forall i \in \mathbb{N}, \text{ where } \mathbb{N} = [1, 2, 3, \dots]\end{aligned}$$

In the above definition, a course can have as many chapters, lessons, and topics as required. However in each topic there are only two main components, Learning Content and Learning Strategy. Learning Content component consists of three elements Content page, Activity page, and Assessment page. While the Learning Strategies component consists of learning objective, Introduction, and Summary elements.

By further adopting mathematical sets to the Learning Content and Learning Strategy components, it can be suggested that the structural components are as below:

$$\text{Learning Content } i = \{\text{Content Page } i, \text{ Activity Page } i, \text{ Assessment Page } i\} \text{ for } \forall i \in \mathbb{N}, \\ \text{where } \mathbb{N} = [1, 2, 3, \dots]$$

$$\begin{aligned}\text{Content Page } i &= \{\text{Content Header, Content Presentation}\} \text{ for } \forall i \in \mathbb{N}, \\ & \quad \text{where } \mathbb{N} = [1, 2, 3, \dots] \\ \text{Content Presentation} &= \{\text{Content Objects, Types}\} \\ \text{Content Objects} &= \{\text{Remembering Objects, Understanding Objects}\} \\ \text{Remembering Objects} &= \{\text{Facts, Procedures/Processes}\} \\ \text{Understanding Objects} &= \{\text{Concepts, Principles}\} \\ \text{Types} &= \{\text{Visual, Auditory, Tactile}\}\end{aligned}$$

Activity Page  $i = \{\text{Activity Header, Activity Presentation}\}$  for  $\forall i \in N$ ,  
where  $N = [1, 2, 3\dots]$

Activity Presentation =  $\{\text{Activity Objects, Types}\}$

Activity Objects =  $\{\text{Examples, Applications}\}$

Types =  $\{\text{Visual, Auditory, Tactile}\}$

Assessment Page  $i = \{\text{Assessment Header, Assessment Presentation}\}$  for  $\forall i \in N$ ,  
where  $N = [1, 2, 3\dots]$

Assessment Presentation =  $\{\text{Assessment Target, Assessment Levels, Assessment Objects}\}$

Assessment Target =  $\{\text{Topic, Lesson, Chapter}\}$

Assessment Levels =  $\{\text{Knowledge, Comprehension, Application, Analysis, Synthesis, Evaluation}\}$

Assessment Objects =  $\{\text{Multiple-choice question, Point \& Click, Drag \& Drop, Fill-in-the-Blank, Interactive Testlet}\}$

In the above definition, the Content page element is any material that has the potential to support knowledge acquisition, performance improvement or behavior change related to the learning objective. It consists of two categories of capability, remembering and understanding which are related to the skilled behaviors of recalling and explaining. We can classify the knowledge content into four sub-categories as suggested by Romiszowski (1983); Remembering objects – Facts and Procedures/Processes, and Understanding objects – Concepts and Principles. In order to accommodate different learner needs, each learning objects in the Content page element is designed with three different formats of presentation; visual, auditory, and tactile.

Activity page element will allow the learner to try the tasks specified in the learning objective, get feedback on their performance and have an opportunity for remediation if necessary. In the above definition, the Activity page element is composed of two types of objects; Examples and Applications. In many cases, for a particular concept or principles, more than one examples or applications will be designed for different learning contexts.

The delivery of assessment models the same hierarchy as the rest of the course. Assessment page elements should be associated with the learning objective and are designed to assess specific outcomes that are taught in the course. In the above definition, there are three types of assessment target at different levels: Topic, Lesson, and Chapter. To model the curricular hierarchy, students should be tested at every level and on very granular specific pieces of information and skills. The assessment should present the learner with a challenging situation, scenario, or question and closely approximate what the desired performance is like on learning. Certain activities are best suited for specific information types. For example, learners can be assessed whether they remember a fact using a multiple-choice question, and an interactive simulation can be used to see if a learner understand a process. Depending on the level of difficulty associated with the content based on Bloom's taxonomy; combinations of assessments can be used to help the learner understand the skills or key concepts.

Learning Strategy  $i = \{\text{Learning Objective } i, \text{Introduction } i, \text{Summary } i\}$  for  $\forall i \in N$ ,  
where  $N = [1, 2, 3\dots]$

Learning Objective  $i = \{\text{Learning Objective Header, Learning Objective Paragraph } j\}$   
for  $\forall i \in N$ , where  $N = [1, 2, 3\dots]$  and  $j = 1$   
Learning Objective Paragraph  $j = \{\text{Text}\}$  for  $j = 1$

Introduction  $i = \{\text{Introduction Header, Introduction Paragraph } j\}$  for  $\forall i \in N$ ,  
where  $N = [1, 2, 3\dots]$  and  $j \leq 2$   
Introduction Paragraph  $j = \{\text{Text, Graphics}\}$  for  $j \leq 2$

Summary  $i = \{\text{Summary Header, Summary Paragraph } j\}$  for  $\forall i \in N$ ,  
where  $N = [1, 2, 3\dots]$  and  $j \leq 2$   
Summary Paragraph  $j = \{\text{Text, Links, Graphics}\}$  for  $j \leq 2$

In the above definition, Learning Strategy components consist of Learning Objective, Introduction, and Summary. A learning objective is the hub of a lesson; it is a performance-based statement that describes the intended instructional result after learners have experienced the learning objects. Each topic consists of only one learning objective. The sum of all the learning objectives associated with specific content forms a lesson. Without a learning objective, the other components cannot be integrated into object-based lesson. The Introduction is to motivate the learner at the beginning of the lesson. It is stated in terms of student-related knowledge, understanding and interests. Normally not more than two paragraphs, sometime appropriate graphic can be used to give the overview of the content. Lastly the Summary is material that reviews contents, and by hyperlink points to further directions for exploration in order to practice and keep the knowledge active. Sometime appropriate diagram can be used to conclude the whole topic content but if the conclusion is described by text, normally not more than two paragraphs.

#### **4. Development and Production**

World Wide Web provides great opportunities to Math educators to utilize and create on-line educational materials. Not only text and picture, but also animation and sound can be used in educational materials on Internet. Many companies made web-ready software, such as Math View by Waterloo Maple Inc, which can be used to manipulate mathematical symbols and draw 2D and 3D graphs in browser windows. At the same time, interactive learning materials from individuals such as Java applets, and Flash are now growing rapidly on Internet. We might be able to find what we need in the near future, and utilize these educational materials for other purposes by making links.

In giving an example on how to apply the model in the design process, begin by choosing a particular learning objective from a textbook and then choosing the appropriate learning objects from the repository to form the reusable object-based lesson. There are three ways to utilize and create on-line educational materials from learning objects, the Unique Learning Objects (ULO), the Dynamic Learning Objects (DLO), and Customized Learning Objects (CLO). The ULO is the individual learning objects that are tagged store in the repository. It is the base component of all lessons, so it can be used to create other unique structures like DLO and CLO. Figure 1 shows how an instructor defines a web page reference (Zobel, 2001), into the database.

Author Name: Edward A. Zobel

Author Organization: Zona Land

Author Email: zona@mind.net

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[Pedagogy Details:](#)

Subject: Calculus & Analysis - 515

Topic: Linear Functions

Title: Linear Functions

Description: Function of the form  $f(x) = m(x) + b$  is called linear function. Its graph is a straight line. There are three different forms of the linear equation

Object Type: Content - Concept

Education Level: University/College

Keyword(s): Linear Functions, Slope-Intercept, Point-Slop

URL (http://): <http://id.mind.net/~zona/mmts/functionInstitul>

Figure 1: Defining a web page reference

Besides being used to recombine to form larger educational interaction, each of these ULOs can be used by learner as an independent learning material to enhance certain concept, principle or idea. When learners needs a specific piece of information, they can navigate to the ULO repository by type in a request, and get the relevant, only needed ULO. Figure 2 shows the sample interface page to search the appropriate ULO and the object details that appears on the learner's screen after retrieve from the repository. This particular object is a web page reference describes about the different types of linear functions in Pre-Calculus.

The screenshot shows a web interface for searching Learning Resources. At the top, there is a navigation bar with a 'Click Here' button pointing to 'myu.com.my' and the 'MYU' logo. Below this is the 'Learning Resources' header. The main content area is titled 'Search Results' and displays the following information for a search result:

- Subject: [515](#)
- Topic: Linear Functions
- Type: Content - Concept
- Level: University/College
- Technical: Any web browsers
- Copyright: Yes
- Title: **Linear Functions**  
Function of the form  $f(x)=ms+b$  are called linear function. Its graph is a straight line. There are three different forms of the linear equation: slope-intercept form, point-slope form, and general form.
- URL: <http://id.mind.net/~zona/mmts/functionInstitute/linearFunctions/linearFunctions.html>

At the bottom of the search results, it says 'Displaying 1 - 1 of Total 1 Records' and 'Page 10 | Next 20'. On the left side of the page, there is a search filter sidebar with the following settings:

- Subject: Calculus & Analysis - 515
- Topic: Linear Functions
- Object Type: Content - Concept
- Education Level: University/College
- Language: English

There are 'Search' and 'Reset' buttons, and a link to 'Advanced Search'.

Figure 2: The ULO search and retrieve sample page.

If they need a more in-depth learning experience, the system will build a lesson based on the learning objective. Each lesson is called as Dynamic Learning Object (DLO). DLO is a template needed to format ULOs for varying delivery media. Individual ULO can be combined to form a larger through the use of learning template that integrate ULOs into the needed format, from web-based courseware to printed materials used in traditional classroom. Each lesson incorporates three known and verified learning strategies: Learning Objective, Introduction, Summary and three learning elements: Content, Activity, and Assessment, as shown in Figure 4 to form instructional experiences which make the acquisition of knowledge more efficient, effective and appealing. Learning objective, introduction, and summary are additional learning strategies which, must be designed and integrated into every DLO in order to create a complete instructional experience. Each of these types of element is extremely non-reusable. So DLO contain information that would be less reusable individually.

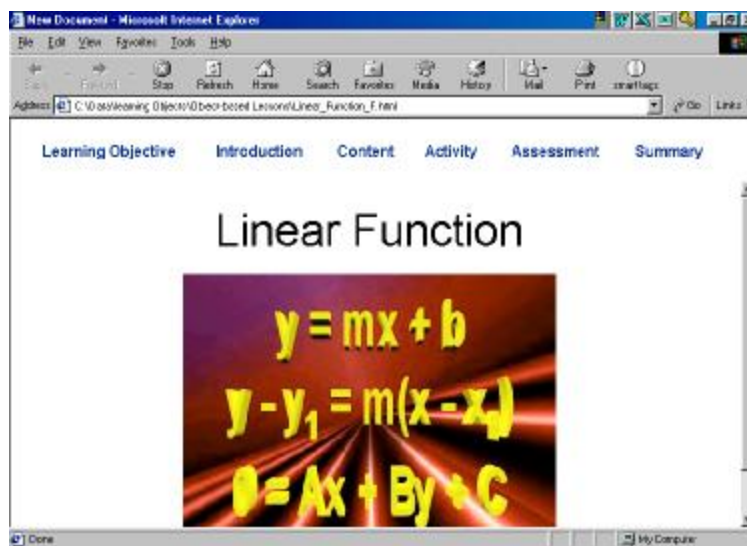


Figure 4: The DLO sample page

Besides DLO, which is a template needed to combine ULOs in original format for varying delivery media. We can also customize the ULOs into CLO, by including the necessary scripts from the ULOs original document with learning strategies. This customized lesson will have better look and feel by eliminating all the unnecessary information or links inside the original reference page. As DLO, each CLO contain information that would be less reusable individually because of the learning strategy elements. Figure 5 shows the sample of a CLO lesson.

From the experiments, most of the learners felt reusable object-based lessons, as a supplement to the traditional lecture and textbook would provide substantial benefits. We asked students to indicate their interest in the ability to access the most updated learning contents from a pool of learning objects to tailor learning content for multiple learners, and to personalise learning content to the needs of individuals offered by object-based learning systems. In each case, a majority of students considered these capabilities to be highly beneficial. Because the learning object approach allows teaching and learning to be cantered on the needs and interests of the learners, enabling learning to occur anytime, anyplace and to allow for greater customisation and flexibility of learning contents at the level of granularity desired.



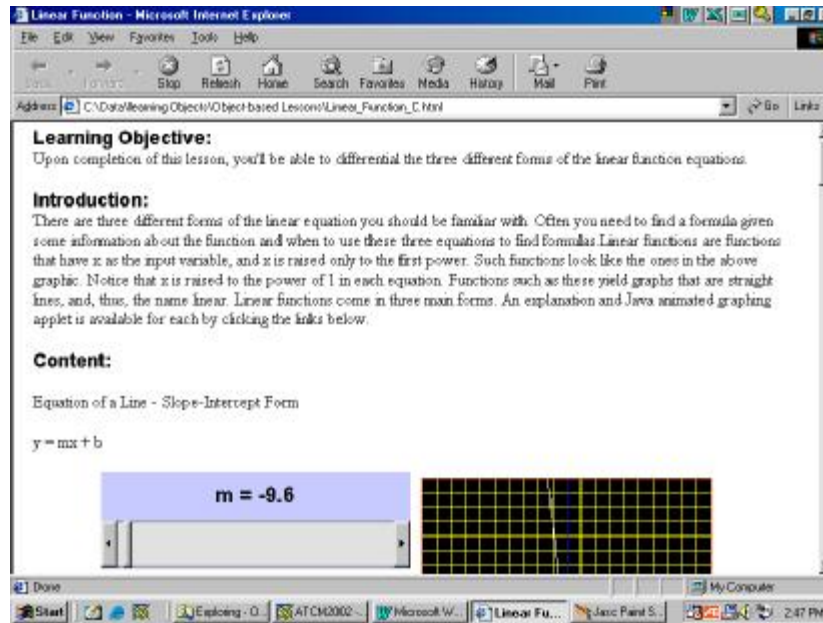


Figure 5: The CLO sample page

## 5. Conclusion

The use of learning object as a part of the design and development process of online learning settings provides a number of advantages. Until now, there has been relatively little activity undertaken to ensure that online learning settings are being designed in way that promote flexible use of the learning resources. This paper has discussed the use of learning objects with sound instructional design principles to define the object-based lesson model, and then highlighted the practical experiences of storing, using and assembling learning objects of particular interest is the ULOs from which multitude of different object-based lesson can be made.

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