Reusable Learning Objects: Let's give it another trial

Bernd J. Krämer

2005
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Reusable Learning Objects: Let's give it another trial¹

Bernd J. Krämer
FernUniversität in Hagen, 58084 Hagen, Germany
Bernd.Kraemer@FernUni-Hagen.de

Abstract

Learning objects (LOs) and computer supported learning settings are topics of high concern in academia and industry. But although hundreds of LO repositories exist these days, LO reuse has not become reality on a broader scale. The nationally funded project CampusContent represents an interdisciplinary research effort investigating question like how must LOs be designed to increase their didactically useful reuse in different learning arrangements and thereby allow the seamless combination of content objects and educational scenarios from different providers. In this paper we present a first analysis of the reasons why LO reusability is still low and introduce a conceptual model of modular learning content that tries to overcome the conflict between context-independence of such modules, which is necessary to increase reusability, and pedagogic context, which is required to make learning effective. We also sketch the draft design of selected interface functionality of the infrastructure we aim to build.

Keywords: learning objects, pedagogy, reusability

1. Introduction

The concept of learning objects arose in the late nineties driven by the motivation to reduce the development and maintenance cost of digital learning content by means of modularization and reusability. Learning objects promised to offer a new way to create and mediate educational content in terms of smaller units of learning that are self-contained, can be re-used in multiple contexts and pedagogic settings and can be grouped into coherent collections of digital learning content. To provide a handle for third-party reuse, learning objects are enriched with metadata – often conformant to the Learning Object Metadata (LOM) standard [1]. LOM provides a conceptual data scheme for characterizing educational materials including content-related, technical, educational and other descriptive attributes.

Learning objects are around for a decade now and we find hundreds of learning content repositories (cf. e.g., [2, 3]) and hundreds of thousands of educational materials on the Web: But still, current reuse practise in learning content is disappointingly low. This may be due to the fact that popular definitions of learning objects as promoted, for example, by the Learning Technology Standards Committee (LTSC) of the Institute of Electrical and Electronics Engineers (IEEE) are too broad. This also holds for Wiley’s own definition (“any digital resource that can be reused to support learning” [4]) who heavily criticized the breadth of earlier definitions. Such definitions provide no operational hints as to what a learning object consists of and what granularity is appropriate to maximize reuse and simultaneously match a given learning context. As a consequence, a query for the term “algorithm”, e.g., in the knowledge pool of the Ariadne Foundation [5] or in MERLOT’s collection of online learning materials [6] may yield a complete course on Internet algorithms presented in terms of video recordings of lectures or a naked Java applet just visualizing the method of working of the depth-first algorithm on a predefined graph (cf. Fig. 3).

¹ This work was sponsored by the Deutsche Forschungsgemeinschaft (DFG, the German Research Foundation) under code number 44200719.
In the next section we argue about the need for a more systematic approach towards reusability. In Section 3 we motivate and briefly review new definitions of learning object. Section 4 discusses an example to illustrate the point about reusability. Section 5 presents a draft conceptual model for mapping learning objects into an educational concept space spanned by a knowledge dimension and a cognitive process dimension. Section 6 finally sketches first ideas about how educational information can be presented unobtrusively to learning object seekers and how it can possibly be mined from existing educational content.

2. Reusability

The CampusContent project set out earlier this year to evolve the state-of-the-art in component-based development of educational content including collection, quality assurance, distribution and reuse [10]. CampusContent represents an interdisciplinary research effort that addresses the question of how content from different providers can be seamlessly combined and didactically usefully be integrated in different learning arrangements. We aim to develop a technical infrastructure including repositories for learning objects and educational scenarios and tools for composing learning content from reusable learning objects. Accompanying community building activities aim to create an actively involved CampusContent community early on.

Although David Wiley compared the idea of building educational content from smaller building blocks with object-oriented programming [4], there is no generally agreed development and reuse concept as it exists, for instance, in software engineering. When people talk about a software object, they refer to a bundle of typed attributes and a set of related methods representing state and behavior, respectively. Design principles such as encapsulation, cohesion, and coupling allow software developers (who compare to educators in the case of learning objects) to develop and maintain objects independently of each other. These principles introduce a clear separation between interface and implementation of an object, they provide a measure about how well the attributes and methods of an object logically cohere and they characterize the interdependence of one object with others. We also find methods supporting design for reuse [7] and we know how to adapt software components systematically to accommodate new needs [8]. Except for Boyle’s attempt to transfer certain software engineering principles like cohesion and coupling to pedagogical principles to encourage the production of reusable learning objects [9], little exists for learning content.

We also observe that learning objects are typically developed in the context of comprehensive educational applications. That is, the alley of reuse is mainly walked along one direction by reusing components that are isolated from a larger content, while the opposite direction of designing atomic components that can be reused is largely ignored. A component development market, as it exists for software components, is not in sight. This one-sided approach to learning objects development often limits the potential for reuse and content developers rarely invest a second effort to increase the reusability of objects they designed for their own purpose, let alone that no practically useful guidelines exist.

3. Basic Building Blocks

Several authors including Baumgartner [12] have described a fundamental contradiction inherent in the concept of learning objects. A learning object’s potential for reuse increases with its degree of independence from any application context, while educators claim that contextuality is the essence of effective learning processes. In [13], Wayne Hodgins argues in a similar direction along the modular Autodesk content hierarchy decomposing into five abstraction layers:

- The most fine-granular level consists of raw media elements including media types like text, audio, illustration, animation and others.
• From raw media elements so-called *information objects* are formed. They describe a certain procedure, process or structure, define a concept, present a fact, or provide an overview on some subject.
• The third aggregation layer combines information objects centred on a learning objective. The objects at this level are called *learning objects* or, more general, *application objects* because marketing and support objects are admitted here, as well.
• The fourth layer groups application objects around a terminal objective to aggregate assemblies like lesson, chapters, learning units etc.
• The top layer includes *collections* of such aggregate assemblies to form thematic courses, books, stories or whole movies.

It is easy to follow Hodgins’ argument that raw media elements are the most reusable elements in the hierarchy because they are highly context-independent, while usability decreases along the hierarchy as context dependencies increase as well. A similar argument has been used by Edgar Dale, but related to learning activities (cf. Fig. 1).

![Fig. 1: Interpretation of Edgar Dale’s Cone of Experience](http://web.utk.edu/~mccay/apdm/selusing/selusing_d.htm)

In CampusContent we slightly modified Hodgins’ definition and focused on the three lower levels, which we populate with media assets, information objects and learning objects, respectively, but only information objects and media objects will be subject to reuse in the CampusContent repository to be built.

**Media assets** are presentational data that are characterized by a *media type* (text, image, video, audio, animation, demonstration etc.) and a *MIME type* (html, tex, doc, tiff, jpg, gif, wav, flash, shockwave etc).

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2 Source: [http://web.utk.edu/~mccay/apdm/selusing/selusing_d.htm](http://web.utk.edu/~mccay/apdm/selusing/selusing_d.htm)
On the second level we distinguish between elementary and composite information objects. Elementary information objects are composed of one or more media assets. Composite information objects are hierarchically composed of information objects. They are associated with metadata including one or more content types. Content types are taken from an extensible vocabulary that is inspired both by Rhetorical Structure Theory [14] and categories of knowledge dimensions [15, 16, 17]. The concept map in Fig. 2 depicts a section of a first draft of information types and rhetoric relations between them. Metadata of composite information objects are computed from the metadata of their constituent objects by uniting corresponding metadata of constituent information objects. Information objects should be closed in the sense that they must have no reference (parts of) other information objects. Any dependence such as assumed pre-knowledge is captured in terms of interface concepts. A debate on whether we need a concept of interface for information objects or whether metadata are sufficient to characterize an object is not concluded yet.

Fig. 2: Content types and their relationships (incomplete)

Learning objects are formed by taking one or more information objects and combining them with an educational object. An educational object includes a learning objective and an educational activity. A learning objective typically refers to a subject area and specifies the targeted learner ability. The educational activity aims to achieve the learning objective and consists of one or more actions an individual or a group of actors is engaged in. The actions describe the intended handling of or interaction with information objects and they refer to services and other resources to be used in the learning process. All information objects included in a learning object should support the learning objective and activity.

Research on conditions and rules of thumb that would allow us to provide guidelines and run plausibility checks for object users is ongoing.

*Multipurpose Internet Mail Extensions; originally designed for typing email attachments, now also used to communicate data type information to Web browsers and Web servers.*
4. Reusability Revisited

The Java applet shown in Fig. 3, which we found in the MERLOT collection of educational materials when searching for the term “algorithm, can be viewed as the media asset of media type “demonstration“ (cause it exemplifies a procedure) and the MIME type “application“ with the subtype “java-applet“. It can also be viewed as an information object if enhanced with content type and suitable metadata. The applet illustrates the method of working of an algorithm, i.e., it reproduces a procedure or dynamic process to help people analyze and understand a procedural concept.

The reusability of this applet in different educational setting is also low because:

- the name of the procedure demonstrated is named in the (header of the) applet code (Depth First Search),
- auxiliary concepts used in the implementation of the procedure (pre-, post-order and stack) are included, and
- the graph to be searched is predefined.

As the procedural concept demonstrated is shown, we can only combine the information object with a learning objective and activity supporting a low level cognitive process such as remembering a procedure [15]. The learning objective could be something like:

“The student is able to explain the procedure of depth-first traversal of a graph as a special search method”.

What we observe here is that the formulation of the learning objective shows the following template: (subject, domain concept, cognitive process). The template could be extended by a component “environment”, which stands for anything like a tool, a method or a service that should be used to support the activity, very much like the notion of environment used in IMS LD.
The recommended learning activity could be specified as follows:

“Watch the demonstration of the depth-first search algorithm and compare it with your knowledge of the concept!”

If the information of what is demonstrated (i.e., the term “Depth First Search”) was omitted from the information object, we could also use the applet to challenge learners analyze the applet’s search behavior and reconstruct the general procedure. If the graph to be traversed could be defined by the learner, and thus different traversal schemes could be applied to it and compared with each other with respect to semantic and performance criteria, we would gain additional flexibility and thus increase reusability.

![Java applet demonstrating two alternative traversal schemes on user-defined graphs](http://www.cosc.canterbury.ac.nz/people/mukundan/dsal/GraphAppl.html)

**Fig. 4:** Java applet demonstrating two alternative traversal schemes on user-defined graphs

The applet in Fig. 4 developed by R. Mukundan shows another solution to the graph traversal problem. It allows the learner to define her own sample graph by establishing connections between (some of) the 16 nodes presented on the center panel and then run both depth-first and breadth-first search traversal to it. But again, the names of the procedures are buried in the user interface of the applet and cannot be made subject to student analysis.

A more comprehensive learning object could be centered on the learning objective:

“The student is able to construct an effective graph traversal algorithm and implement it in Java.”

and the following learning activity:

“Read through the conceptual definition of depth-first traversal (this would refer to another information object of content type ‘fundamental’ and ‘definition’ in which the procedure is explained), analyze the behavior of the simulated algorithm (this would refer to something like one of our previous applets), and construct a depth-first algorithm that operates correctly on any finite directed graph.”

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4 [http://www.cosc.canterbury.ac.nz/people/mukundan/dsal/GraphAppl.html](http://www.cosc.canterbury.ac.nz/people/mukundan/dsal/GraphAppl.html)
In an empirical study of the popular MERLOT repository [18], Heyer found that the majority of learning resources integrate several information objects and educational components in a fixed, immutable way, which implies that the degree of reusability is extremely low. To provide a higher degree of reusability for elements in the CampusContent collection, we envision an organization and interaction interface that allows content developers to combine information objects and abstract versions of educational components flexibly. Figure 5 schematically illustrates how different information objects can be combined with different educational objects.

**Fig. 5:** Combining information objects with learning objectives and activities

The flexible combination of information objects and educational objects requires, however, that we are able to decorate these objects with suitable metadata that allow us to understand and check the conformance of objects from different angles: media type, content type, subject area, knowledge dimension and the cognitive process dimension. The “subject area” may be balanced on the basis of suitable subject ontology, while the pedagogic aspects will be understood on the basis of appropriate pedagogical taxonomies and models.

To give a better clue of what we refer to, Section 5 will briefly review our pedagogic approach in terms of Anderson and Krathwohl’s variant of Bloom’s well-known taxonomy [15].

### 5. Pedagogical Taxonomies

In [18] we showed how educational taxonomies can be applied to qualify and relate learning objectives and activities. These results used Anderson and Krathwohl’s taxonomy of cognitive processes [15] shown in Table 1. Like other pedagogical taxonomies, it aims to support instructional design processes. We chose this one to begin because it is widely used in many topic areas. But it is important to notice that our concepts and technical solutions will not depend on a single taxonomy but will allow systems users to import their favorite taxonomy and still use the system’s functionality.

The taxonomy spans a pedagogic concept domain between the two axes: a Knowledge Dimension, which characterizes basic knowledge types, and a Cognitive Process Dimension, which organizes categories of cognitive capabilities in a hierarchy whose upper level category includes all capabilities of lower levels.
We plan to use concept spaces like this to type learning objectives and recommended activities with pedagogic information. For this purpose, it is useful that [15] provides a number of sub-categories and examples in the cognitive process dimension. What still needs to be done, however, is the identification of typical activities supporting a particular cognitive process.

We are also pursuing research on possible rules and hints we could provide for information and education object users to give them helpful feedback on intended object combinations. Indeed, Anderson and Krathwohl [15] found that there exist strong correlations between knowledge types and cognitive processes, at least for the first three categories of the cognitive process dimension; Factual knowledge is heavily correlated with the process of remembering, conceptual knowledge is best be acquired through the process of understanding, and procedural knowledge is strongly correlated with cognitive processes of applying.

We are quite optimistic that with this pedagogical decoration of learning objects we can build a bridge to relate IMS Learning Designs (LD, [11]), which we consider a promising context for embedding learning objects in particular pedagogical models and larger pedagogic scenarios targeted for concrete educational settings. We also hope that LD environments could provide a standard runtime environment for learning objects in the future.

In the following section we present first speculations of possible user interface functions helping users to maintain and use pedagogic information related to learning objects.

### 6. Handling Educational Components

An empirical analysis of the access behavior of the Ariadne Pool users revealed that a majority of users (75%) query with no more than three keywords and a high percentage of the keywords used refer to topical and content type information but hardly anyone actively searched for pedagogic attributes maintained in the repository.

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5 Retrieving relevant knowledge from long-term memory.
6 Construct meaning from instructional messages, including oral, written, and graphic communication.
7 Carry out or use a procedure in a given situation.
8 Break material into its constituent parts and determine how the parts relate to one another and to an overall structure or purpose.
9 Make judgments based on criteria and standards.
10 Put elements together to form a coherent or functional whole; reorganize elements into a new pattern or structure.
For our project this creates two challenges:

1) We need to find a smooth way to introduce learning object seekers to pedagogic information maintained in our repository.

2) As content providers are unlikely to fill-out forms with pedagogic metadata, we need to find ways to mine as much as possible of this type of meta-information from the educational material itself and from its context of use.

Searching in information repositories can be distinguished in two categories: exact search and fuzzy search. An exact search requires that users know what they are looking for and they can, e.g., use a list of keywords or a regular expression to specify their goal. A fuzzy search may yield results in which the search terms may not even occur in the matched documents. Browsing is also a form of fuzzy search. Users can be drawn into a context they were not intentionally looking for.

Figure 6 shows a screenshot of a fictitious search engine interface to the CampusContent repository we are currently designing. We assume that the main window for specifying queries and presenting matches in the center lists a collection of information and learning objects that match the keyword “algorithm”. In the window pane to the right we might find a list of most frequently matched objects, most recent uploads, etc. and a miniaturized semantic map, which we hope would attract the user’s attention.

Let’s assume that the user became curious and click on the semantic map to open a new window with a larger version of the map (cf., Fig. 7). This map structures and visualizes the collection of learning objects that matched the previous search according to cognitive process dimensions. We assume that no explicit metadata for such categories are associated with the learning objects in our repository so that no exact search with cognitive categories were possible, let alone that most users would not search for such categories, at least for now. Rather we assume that this information was mined from the media assets, learning objective and learning activity descriptions and maybe even from different contexts of use.
The user might now want to click one of the spots in the map and a little pop-up window would appear showing the content type and name of the selected object (see Fig. 6). The user could also click on the labels of the clusters to obtain more information on cognitive process categories and best practice examples, which might trigger further exploratory action in knowledge and cognitive process categories.

To enable the explicit specification of such pedagogical metadata, we intend to provide predefined templates simplifying the formation of learning objectives and learning activities upon upload of learning objects and educational objects. The content author would just select a proper template instantiate its formal parameters, such as content types, types of information objects etc., with concrete values or references and produce a readable version of the intended learning objective or a learning activity. The system would associate the type information derived from the selected template and correlate the author’s final formulation of learning objective and activity with the learning object to be uploaded. The templates will likely be supported by a pedagogical ontology, i.e. a conceptualization of knowledge categories, cognitive processes and supporting activities. All of this is subject to ongoing research in the CampusContent project.

![Diagram of cognitive process clusters]

Fig. 7: Semantic map of learning objects organized in cognitive process clusters

7. Conclusions

This article presented conceptual ideas and preliminary results of a new project aiming to make eLearning with reusable learning objects more effective with respect to quality learning content production, to ease the consideration of pedagogical knowledge and increase the sustainability of educational content. We argued that learning object reuse and repurposing are not satisfactorily supported by current solutions of learning object repositories and modular educational content. We drew on principles, methods and models from software engineering that aim at maximizing productivity and reuse, while minimizing maintenance and evolution costs.

We presented first results of the project in terms of basic concept definitions including pedagogical facets. On the conceptual level, emphasis was placed on establishing a coherence between information objects, predefined categories of learning objectives and templates for pedagogical markup as we
started from the assumption that content alone is unable to constitute a useful educational setting. Finally, we outlined some preliminary functionality aiming to make our repository pedagogy-aware. These issues are the subject of ongoing research and development in our project.

References

[10] CampusContent project Web site: http://www.campuscontent.de/