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PEDAGOGICAL ENRICHMENT OF INFORMATION OBJECTS

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ABSTRACT

This paper presents a distinction between content parts (information objects) and educational parts of learning objects. A plea is made for the separation of content and educational context references to maintain the content's high potential for reusability. Since content alone does not constitute a didactical situation, however, after its separation content needs to be enriched with educational elements such as learning objectives and learning activities. This paper proposes ways of rejoining content with educational elements in a repository by means of an educational objectives taxonomy. The taxonomy could be further implemented to collect data on the different pedagogical purposes an information object was used for. Pedagogical repurposing, however, is not just understood as a reuse within different subject matter but also as a reuse for different pedagogical goals, such as the promotion of higher cognitive processes in learning.

INTRODUCTION

The Learning Object vs. the Information Object

Since the idea of learning objects has been introduced, conceptual discussions vary. Polsani (2003) reviewed definitions of learning objects starting from the time that Hodgins introduced the term in 1994. He came to the conclusion, that "a learning object is an independent and self-standing unit of learning content that is predisposed to reuse in multiple instructional contexts" (Polsani, 2003:4). The Sharable Content Object Reference Model (SCORM) defines technical requirements for such content in the form of "-ilities": reusability, accessibility, durability and interoperability (ADL, 2001:1-3). Pedagogical requirements have not been looked into as detailed.

The most regarded aspect of learning objects may be reusability. What does being 'reusable' mean for content? Baumgartner & Kalz (2005) argue that in order to maintain a high reusability of learning objects, they should be separated from their instructional context. That means that the part of the learning object containing the content has to be separated from the part that contains educational context references or other specifications that limit the content to one specific instructional purpose. After the separation, there are two elements that comprise the learning object: the information object, containing just the content, and the educational object, containing educational references, activities and learning objectives (Baumgartner, Bobrowski, Heyer, 2005). This separation enables the information object to be reused with fewer limitations to an instructional context. Only after the information object is tied to a learning objective and learning activity, it becomes a learning object.

This concept relates to the established and widely cited autodesk content model (shown in Figure 1) to the extent that information objects are still accumulated to build learning objects. However, our approach differs in the way learning objects are created by associating an assembly of coherent information objects with educational context. While information objects are defined as the information or content holders, learning objects are not just the mere accumulation of content any longer.

Example

An example for a learning object is shown in Figure 2. Depicted is an interactive Flash simulation in the upper half and a quiz on the bottom half of the learning object. From our point of view, this learning object contains a content part (the simulation) and an educational part (the quiz). The educational part includes an implicit learning objective, which could be summarized by "students will be able to apply arithmetic sequence algorithms".

Black-box reuse, i.e., reuse without affecting the code of an object, requires to adopt the entire learning object as is. Its most reusable part is, however, the simulation, which allows for countless combinations with different learning tasks to accommodate multiple educational purposes. These purposes could range from asking students to provide rationale why the displayed function will always produce linear sequences to having students analyze how the simulation's source code would have to be adopted to display simple exponential functions. The attached quiz at the bottom actually reduces the reusability of the learning object a lot: another user might find the quiz questions too easy and would rather define own questions, or just use the simulation without the quiz.

To increase its reusability, we propose to separate the learning object's content part (the Flash simulation) from its educational facet (the quiz). To enhance the reusability of information objects even further, Bobrowski & Nowaczyk (2006) extended Boyle's approach (2003) and proposed to apply software engineering principles such as coherence, decoupling and parameterization to the design of information objects.

Advantages of distinguishing between information and educational elements

The advantage resulting from this view of separating content from educational uses is that it allows defining learning objects with more precision. Before, learning objects were content: they could contain learning activities, like quizzes, or they could not. Now, we are able to tell if a piece of content is 'just' an information object, which is capable of being connected to different educational purposes, or if it is a complete learning object already containing learning activities and therefore being limited to its intended instructional purpose.

This separation of concerns also enables us to create richer learning situations, since we do not just focus on sequencing content but we are also focused on the number and relations of pedagogical support we entwine in the learning situation. As Krämer & Schmidt (2001:199) stated, "the mere sequencing of SCOs [sharable content objects] in a SCORM compliant learning application does not provide sufficient insight into required and provided capabilities including pedagogic categories such as skills, understanding and competencies". With the separation, we are able to regard SCOs as information objects and augment them with educational metadata to fulfil parts of the condition set by Krämer & Schmidt.

Problematic concerning this separation of information and educational elements is that once the two facets are split, we need to find descriptive and computational mechanisms to identify and rejoin content with fitting educational elements.

The goal must be to rid content as much as possible of its educational context and references to allow for a maximum degree of reusability. Then, as the content is being reused, the content is augmented with educational context and possibly former educational references to provide a meaningful learning situation since content alone does not constitute a didactical situation (Klebl, 2004:3).

Definition of multiple instructional contexts

According to Polsani's (2003) definition, a learning object should be reusable within "multiple instructional contexts". What does this mean? The most obvious thought that comes to mind is the reuse in different fields of subject matter. However, from a pedagogical point of view, reuse for different instructional contexts could also mean that a resource is in one instance being used to teach facts that ought to be *remembered*, and in another instance, the same resource is used to teach concepts or procedures that students are to *apply*. *Remember* and *apply* represent two different cognitive levels of activities that students would have to perform. These two activities would then in turn require two different instructional settings. Varying instructional contexts is therefore not limited to a change in topic or subject matter but also in a change of the pedagogical purpose.

Community needs in regard to learning objects

Only speculations can be made about community needs since there is little data available on learning object usage, as yet. But, as Sosteric & Hesemeier (2002) state, it would be beneficial to have information about how a piece of content was or is to be used. If ways are provided to help users identify how an information object is used for learning, in their view, a true learning object is created because such observations might provide insight into the learning objectives pursued and learning activities performed. Just as placing a word like "calf" into a sentence creates meaning for the word (Downes, 2003), analogously, placing an information object into a learning arrangement with objectives and activities creates meaning for the content. The different meanings that were thus attached to an information object should then be collected to obtain educational context references.

Sosteric and Hesemeier expressed a consequential thought, since it reflects several other opinions that have risen within the community. For instance, Anderson & Krathwohl (2001:40) intend that the instructors decide how to use content, and only through the application of a teaching strategy does the content convey a certain type of knowledge that was not present within the content itself. Similarly, Downes (2003) and Duval (2005) regard learning objects only valuable if we know what context they were used in. Downes (2003:6), quite similar to Anderson & Krathwohl (2001), states that information is not inherent in the learning object itself but is created as the learning object, in our case the information object, is placed into a learning context. More simply, as Duval (2005) put it, "if content is king, then context is queen".

The important measure is to capture the different types of usages of an information object to obtain data on its pedagogical potential. This potential, however, should not just be reflected in a different topical reuse but also across different levels of learning, i.e., lower and higher cognitive processes. We are then required to collect the user data that allows us to learn how a resource was used in different contexts. Storing this information separately in metadata, we call this dynamic metadata, keeps the information object reusable in its original format and at the same time heightens its reuse potential since former context relations may be restored.

Objective

This paper investigates ways that allow the repurposing of content (information object) to different pedagogical needs by combining content ad-hoc with pedagogical elements (learning objectives, learning activities etc.). Since the latter also serve as pedagogical context indicators, a system to collect and organize such pedagogical context metadata for information objects is proposed.

CONNECTING INFORMATION OBJECTS TO EDUCATIONAL CONTEXTS

Current practice

Exemplary, the Multimedia Educational Resource for Learning and Online Teaching[1] (MERLOT) referatory has already implemented an approach for linking educational exercises to content. They incorporated an assignment function[2], which allows the materials in MERLOT to be enhanced with learning activities.

The advantage of collecting assignments that instructors designed for the resources in MERLOT is that these assignments describe the educational context in which a resource was implemented. It gives other users of the resource ideas about how they may apply the resource. At the same time, the content is kept separate so as to keep its reusability potential high.

Figure 3 shows an example of a linked information object in MERLOT: *Ohm Zone*. It is classified as an information object because it provides a simulation that allows several learning activities to be attached to it. Registered members of MERLOT added two *assignments* (learning activities) to this resource, one of them can be partially viewed in Figure 4.

Deficiencies of the current practice

Although the approach is laudable, there are problems with the MERLOT implementation. Only few materials linked in MERLOT fulfil the criteria for reusable content (Heyer, 2005). A wide range of materials, such as resources containing many internal references to other content sections, or websites containing hundreds of external links, certainly obstruct the attachment of learning activities at a granular level. Aggregating such resources into lessons seems hard to accomplish (Boyle, 2003). Additionally, due to the Google-like text based results list, users are not able to quickly distinguish materials that were augmented with learning activities from materials that were not. Relevant pedagogical information is then only available if the link to an assignment is followed, further slowing the process of user decision making.

[1] http://www.merlot.org

[2] http://www.merlot.org/home/Assignments.po

Proposed solution

Looking at the deficiencies while keeping in mind the goal set in the beginning to separate content from educational context, the project CampusContent[3] proposes an alternative solution. This paper focuses on some of the pedagogical measures that were developed to help organize and combine information objects and learning activities.

A taxonomy of educational objectives (Anderson & Krathwohl, 2001) is integrated as a linking mechanism. The taxonomy is a modification and extension of the popular taxonomy by Bloom. Table 1 portrays the taxonomy. Its main function is to help users classify learning objectives, learning activities and assessment instruments into categories of cognitive processes and knowledge types, thus creating a representation of the diversity of instructional design and practice. The characteristic of the taxonomy is that the higher categories integrate the lower ones. For example, the cognitive process *analyze* integrates the cognitive processes *apply*, *understand* and *remember*, while in the other dimension *conceptual knowledge* integrates the category *factual knowledge* and so forth.

The reason, why the Anderson & Krathwohl taxonomy (2001) is predestined to serve as an agent for linking content and educational elements, is its versatility (it spans across different achievement levels and subject matters; Anderson & Krathwohl, 2001:39) coupled with its two-dimensional structure (it incorporates both cognitive process and knowledge dimensions).

Implementing the taxonomy as an educational guide in augmenting information objects serves the following functions:

- It allows allocating what types of knowledge and cognitive processes have been associated with a resource, therefore gaining insight into the educational potential of a resource.
- It allows defining what cognitive stages and knowledge types a learner has passed through while completing a lesson or learning activity.
- It allows accounting for pedagogical diversity in a course, therefore helping instructors visualize their range of applied teaching strategies. If an instructor applies varied techniques that cover several cognitive processes and knowledge types, the taxonomy table will be evenly filled. If the instructor, however, focuses on limited strategies that require only few cognitive processes, the taxonomy will have a skewed distribution.

If an ontology of technical terms and relations is implemented as a second organizing schema, the taxonomy will further serve the following functions:

[3] http://www.campuscontent.de

- A topic or domain can be searched for specific cognitive process or knowledge types, quickly distinguishing, for instance, higher from lower cognitive processes.
- A profile of a specific topic or subtopic can be extracted representing the topic's current pedagogical potential and diversity.

The integration of the taxonomy by Anderson & Krathwohl (2001) into a repository of information objects, learning objectives and recommended activities is shown as a class diagram in Figure 5. Since *object* is a reserved term in object-oriented programming, the information object is called *Resource* in the class diagram. The class "educational scenario" currently serves as a placeholder; its connections to the other classes and attributes are still work in progress.

We strive to have users, potentially instructors and learners alike, mark all resources in the CampusContent repository with metadata regarding the described taxonomy. Then we are able to execute the specified functions with best practice. The following three case studies illustrate in more detail the setup and functions of the CampusContent repository.

Case Study 1: An existing resource is enriched by a user

If we assume that simulation and quiz in Figure 2 were not connected as a learning object but separated into its content and educational parts, a user could find the simulation by searching for the term "arithmetic sequence" in the repository. Upon access, the user may notice that a quiz she uses in her teaching fits the simulation perfectly. She uses the "Would you like to help others use this resource?" function of the repository to connect her quiz to the resource. She uploads the quiz, which may presumably be the two quiz questions shown in the lower half of Figure 2. As she uploads the quiz as a learning activity, she is asked to categorize the learning activity along with the associated resource according to the Anderson & Krathwohl taxonomy. The types of questions asked within the quiz are indicators of the cognitive level and types of knowledge that the students are expected to acquire and train. Since the higher categories integrate the lower categories within each dimension, the entry into the taxonomy table is only done for the highest possible value that the learning activity fosters in regard to the resource.

The first quiz question reads, "What is the common difference in the arithmetic sequence 20, 18, 16, 14, 12,…?". Because the quiz question requires the use of *knowledge of subject-specific skills and algorithms*, which is a subtype of procedural knowledge (cp. Table 2), the category for the knowledge type would be *procedural knowledge*. Likewise, the quiz question demands that this knowledge is *applied* (cp. Table 1) since the calculation algorithm has to be performed by the students. The second quiz question aims at the same level of knowledge and cognitive process. Even though there are two questions, the uploaded quiz is regarded as one activity and will thus produce one entry for the simulation's taxonomic table. Therefore, the counter for the cell of the resource receives an entry as shown in Table 3.

The same process is repeated for every learning activity (such as, "Change the values in the simulation to produce outcome {X}, and record your findings") that is linked to the simulation in Figure 2. After the resource has been linked to several learning activities, a distribution will be visible in the resource's taxonomy table. The distribution indicates what educational value the information object holds. A sample distribution for the simulation resource is shown in Table 5. The cells marked with dark red received more entries, meaning more activities were linked joining these two categories, than the cells marked with a light red. Cells without any coloring (white background) received no entries. For Table 5 this means that no activities fostering higher cognitive processes were associated with this resource.

An even distribution of color within the table would indicate that the information object or resource is capable of supporting multiple levels of knowledge types and cognitive processes. If a resource, however, tends to get only entries for a few cells that are close together, the resource may be limited in its capacity to be applied for a wide range of knowledge types and cognitive processes.

The graphical presentation of a taxonomic table associated with a resource as shown in Table 5 is accompanied by a textual explanation what the distribution could mean. Text for this purpose is saved within the repository and shown upon request (selecting: "what could this distribution mean pedagogically?").

If a user on the other hand is unsure about cognitive processes and just wants to select a knowledge type for a resource, he can do so. The system will couple the selected knowledge type automatically with the cognitive process *remember* since that process symbolizes the lowest level of learning to be expected.

Case Study 2: A user augments a resource through semi-automatic support of the system

We cannot expect that all users will be able to use a taxonomy of educational objectives as the one proposed by Anderson & Krathwohl (2001). Therefore, a system to support the augmentation of information objects must be implemented as well. There will be no mandatory functions that users have to perform, only optional ones.

For scaffolding purposes, the repository features a learning objective generator. The generator supports users during the creation of learning objectives for content. In this instance, the taxonomy serves as a suggestive mechanism.

Within the taxonomy, there exist innate correlations between certain types of knowledge and cognitive processes: these are correlations between *factual knowledge* and *remember*, between *conceptual knowledge* and *understand*, as well as between *procedural knowledge* and *apply* (Anderson & Krathwohl, 2001:239f). Relations with other types of knowledge and cognitive processes are not as strong as the three pairs mentioned, yet, they could be assumed. Refer to Table 4 for a graphical representation of the corresponding knowledge types and cognitive processes. The less strong correlation is indicated with a grey bar as opposed to black bars for the stronger correlations.

The learning objective generator would, as the resource is uploaded or accessed, provide the option to augment the resource with a learning objective. The system would then ask the user, how the resource was or is to be used, i.e., what the result of the learning process should be. Table 2 shows subtypes of the knowledge categories according to Anderson & Krathwohl (2001), which shall help users determine for what purpose the content can be used.

For instance, regarding the information object *Ohm Zone* shown in Figure 3, from a set of questions the learning objective generator provides, a user might affirm to, "Do you use the resource to have students *apply* a law or rule?". Laws and rules may be classified as *knowledge of subject-specific skills and algorithms* (refer to Table 2). Since Ohm's law can be identified as a law, this would be a correct classification. The cognitive process *apply* is directly linked to it due to the innate correlation. The question asked by the learning objective generator is already stated containing both elements that are essential for learning objectives: the cognitive process and the knowledge (Nitko, 2004; Anderson & Krathwohl, 2001). If the user answers the question with "yes", the assigned learning objective for the *Ohm Zone* information object would be, "The learner will be able to *apply* a *law*" or alternatively "The learner will be able to *apply* Ohm's law" with free text entry performed by the user. At the same time the learning objective is generated, the system counts one entry for the corresponding cell (procedural knowledge/apply) in the resource's taxonomy table, as exemplarily shown in Table 3.

Naturally, there are other knowledge and cognitive process relations possible for the *Ohm Zone* resource. However, the semi-automatic system may not distinguish the use of the resource – the users have to do that. If the resource is repeatedly used to have learners *apply* a type of *procedural knowledge* as in the case demonstrated, then the resource's potential for pedagogical repurposing might indeed be limited to that purpose. This, nevertheless, reflects a concrete pedagogical expression for the purpose of the resource.

Depending on the collected data, a profile for the resource can be established. This consists of a graphical representation (as demonstrated in Table 5) as well as a textual explanation.

Other possibilities for semi-automatic suggesting include analyses for similar metadata across resources, learning objectives and learning activities as well as text analyses of resources and learning activities to point out similarities (Bobrowski, 2005).

Case Study 3: The system supplies dynamic metadata for a resource

Starting from the assumption that the most common way to search in a repository is the topic related search, improved ways to supply users with pedagogical information about resources arise. We are not expecting that people will look for assignments before they did not locate or select resources.

Since it is impossible for one person to look at a piece of content or resource and determine all of its potential contexts to which the resource may be applied, a long-term collection of different user data has to be integrated. Case studies 1 and 2 portrayed two possible ways to collect such data. This is accomplished in a repository environment since random user tracking on the World Wide Web is momentarily hard to accomplish.

If the user has decided to use a resource, i.e. an information object, she has already decided on a relevant topic. What the user would then need is a quick overview of the pedagogical potential that the resource and its referred learning activities hold. This can be derived from the activities that were attached to the resource via identifiers. The user would be shown a graphic similar to the one in Table 5 that is placed next to the resource's title and (short) description. Using this interactive graphic, she could now determine what level of cognitive process, what knowledge type, or what combination of the two she prefers. With one click, she selects the corresponding column, row, or cell directly in the taxonomy graphic. Instantly, the referred learning objectives and learning activities that fit the selected criteria are presented to her. This way she could avoid looking through 20 assignments since she is just presented the activities that fit her teaching criteria.

If the user then selects an activity from the suggested ones, it will be coupled with the resource to form a learning object. As the user aggregates increasingly more learning objects and lessons, a different graphic of the Anderson & Krathwohl taxonomy table is constantly shown to the user to track the pedagogical accumulation of resources. This way, the user would be informed how pedagogically balanced her created learning objects and lessons are. If she then opts for other cognitive processes or knowledge types, the system can suggest related resources and activities in accordance to her search specifications.

This system may not just be used with resources but with entire domains. If the Anderson & Krathwohl taxonomic profiling system for resources is coupled with a technical thesaurus, the user is, for instance, able to perform searches for *hydraulic pumps* that were matched with *procedural knowledge* (optional) and that incorporated at least the cognitive process *analyze*.

Finally, the system could automatically check if the selected learning objectives match the integrated learning activities. Since learning objectives and learning activities are both classified into the taxonomy, a mismatch can be easily detected. The learning activities have to be at least at the same level of knowledge type and cognitive process to fulfil the objective. Outperforming the objective with activities that integrate higher cognitive processes and knowledge types, however, is not a problem.

CONCLUSION

This paper first introduced a distinction between learning objects and information objects. Likewise, it was argued that content alone as a measure for learning objects is not sufficient: if all we needed was content, we also wouldn't need universities since libraries would do the job (Wiley, 2006). Then we proposed to widen the definition of multiple instructional uses to include multiple pedagogical purposes, not just multiple topical purposes. Using a taxonomy of educational objectives, it was then shown how pedagogical augmentation of content as well as the fostering of a diverse use of cognitive processes and knowledge types could be implemented.

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REFERENCES

Advanced Distributed Learning Initiative – ADL, 2001, "Sharable Content Object Reference Model, Version 1.2: The SCORM Overview," Available online at http://galileo.enc.org/~library/scormover.doc [February 23, 2006].

Anderson, L.W.; Krathwohl, D.R. (eds.), 2001, *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives*, Addison Wesley Longman, New York.

Baumgartner, P., Bobrowski, S., Heyer, S., 2005, "Towards a Model of Learning Objects," currently under review for *Technology, Instruction, Cognition, and Learning,* Special Issue: Learning Objects and Pedagogy, edited by Marie Duncan & David Wiley.

Baumgartner, P., Kalz, M., 2005, "Wiederverwendung von Lernobjekten aus didaktischer Sicht," *Gesellschaft für Medien in der Wissenschaft - Proceedings*, September 13-16, 2005, Waxmann, Rostock (in German).

Bobrowski, S., 2005, "Passgenauigkeit von Informations- und Bildungsobjekten für verschiedene Kompositionsmechanismen von Lernobjekten". Unpublished Report, FernUniversität in Hagen, (in German).

Bobrowski, S., Nowaczyk, O., 2006, "Adapting Software Design Principles to Enhance the Reusability of Learning Objects", submitted for publication to *e-learning and education*.

Boyle, T., 2003, "Design Principles for Authoring Dynamic, Reusable Learning Objects", *Australian Journal of Educational Technology*, 19(1), pp. 46-58.

Downes, S., 2003, "Learning Objects in a Wider Context," CADE 2003. Presentation available online at http://www.downes.ca/files/widercontext.ppt [February 23, 2006].

Duval, E., 2005, "LearnRank: the Real Quality Measure for Learning Materials," *INSIGHT*, December 6, 2005. Available online at http://insight.eun.org/ww/en/pub/insight/thematic_dossiers/articles/quality_criteria/equality5.htm [February 23, 2006].

Heyer, S., 2005, "An Analysis of Learning Resources Using a Cognitive Process Taxonomy" in M. E. Auer, U. Auer, R. Mittermeir (eds.), *International Conference Interactive Computer Aided Learning 2005: Ambient and Mobile Learning*, University Press, Kassel.

Hodgins, W., 2001, "Food for Thought: The REALLY Big Picture, of the Next, Next Generation of Content, Learning & Performance," Presentation at the LearnTec 2001 Conference held in Orlando, Florida, October 30-31, 2001. http://www.learnativity.com/speaking/TL2K1-Food4Thought.pdf [February 23, 2006].

Klebl, M., 2004, "Lehrprozesse planen, Lernprozesse strukturieren mit IMS Learning Design," DSpace Service of the Open Universiteit Nederland (in German) http://hdl.handle.net/1820/234 [February 23, 2006].

Krämer, B., Schmidt, H.W., 2001, "Components and Tools for On-line Education," *European Journal of Education*. Vol. 36, No.2, pp. 195-222.

Nitko, A.J., 2004, *Educational Assessment of Students. Fourth Edition*, Pearson Prentice Hall, Upper Saddle River, NJ, Columbus, OH.

Polsani, P.R., 2003, "Use and Abuse of Reusable Learning Objects," *Journal of Digital Information*, Vol. 3, Issue 4. Available online at http://jodi.ecs.soton.ac.uk/Articles/v03/i04/Polsani/ [February 23, 2006].

Sosteric, M., Hesemeier, S., 2002, "When is a Learning Object not an Object: A first step towards a theory of learning objects," *International Review of Research in Open and Distance Learning*, Available online at http://www.irrodl.org/content/v3.2/soc-hes.html [February 23, 2006].

Wiley, D., 2006, "RIP-ping on Learning Objects" Iterating Toward Openness. Blog entry from January 9th,

2006. http://opencontent.org/blog/archives/230 [February 23, 2006].

FIGURES AND TABLES

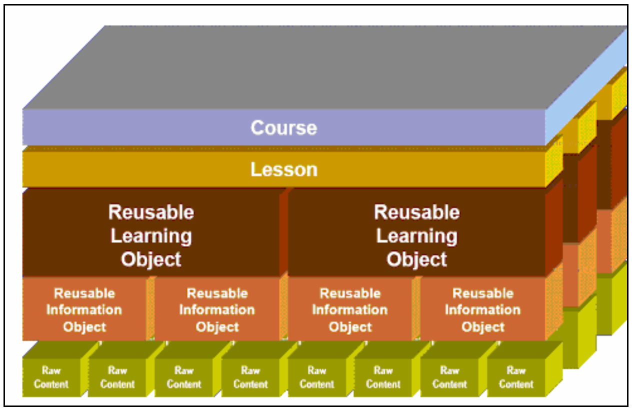

Fig. 1 Autodesk Content Model (Adopted with slight modifications from Hodgins, 2001).

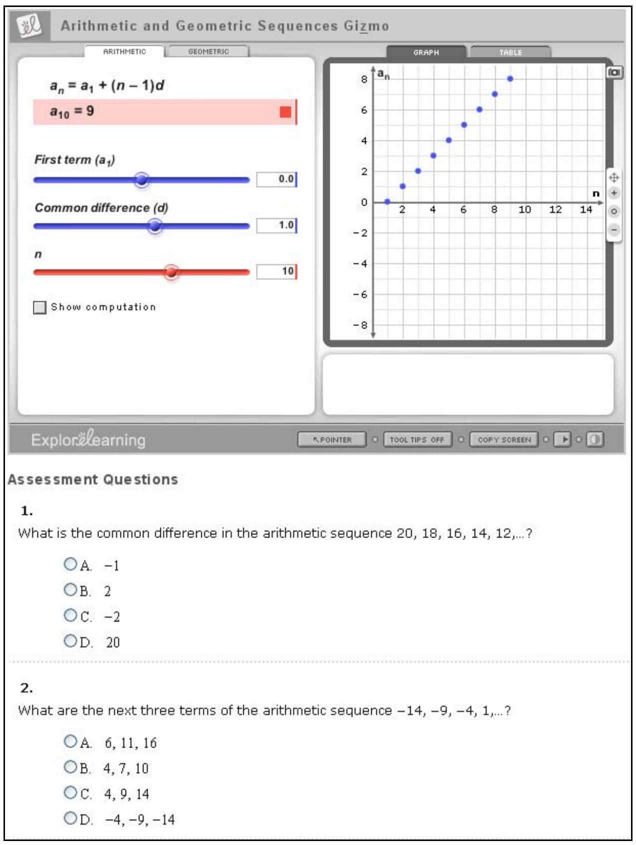

Fig. 2 Excerpt of a Learning Object by ExploreLearning. http://www.explorelearning.com/index.cfm? method=cResource.dspView&ResourceID=340 [February 23, 2006]

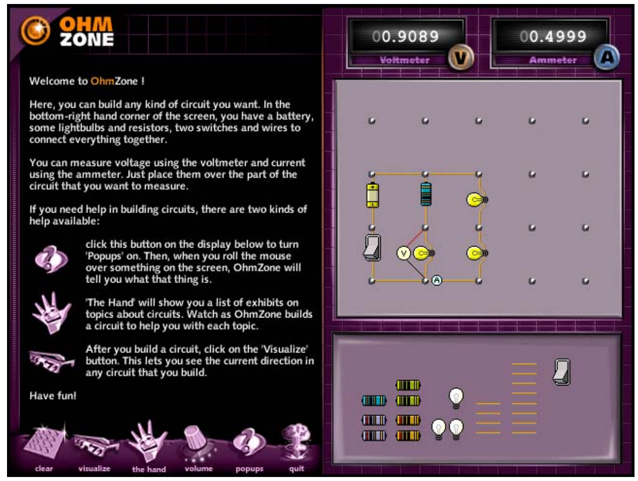

Fig. 3 Information Object *Ohm Zone*. http://www.article19.com/shockwave/oz.htm [February 23, 2006]

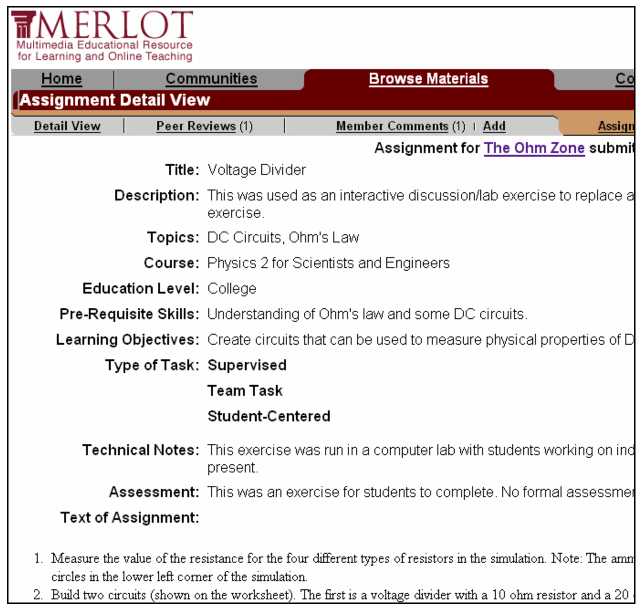

Fig. 4 Excerpt of an assignment for *Ohm Zone*. http://www.merlot.org/artifact/PedagogyDetail.po? pdgOid=10100000000000020517 [February 23, 2006].

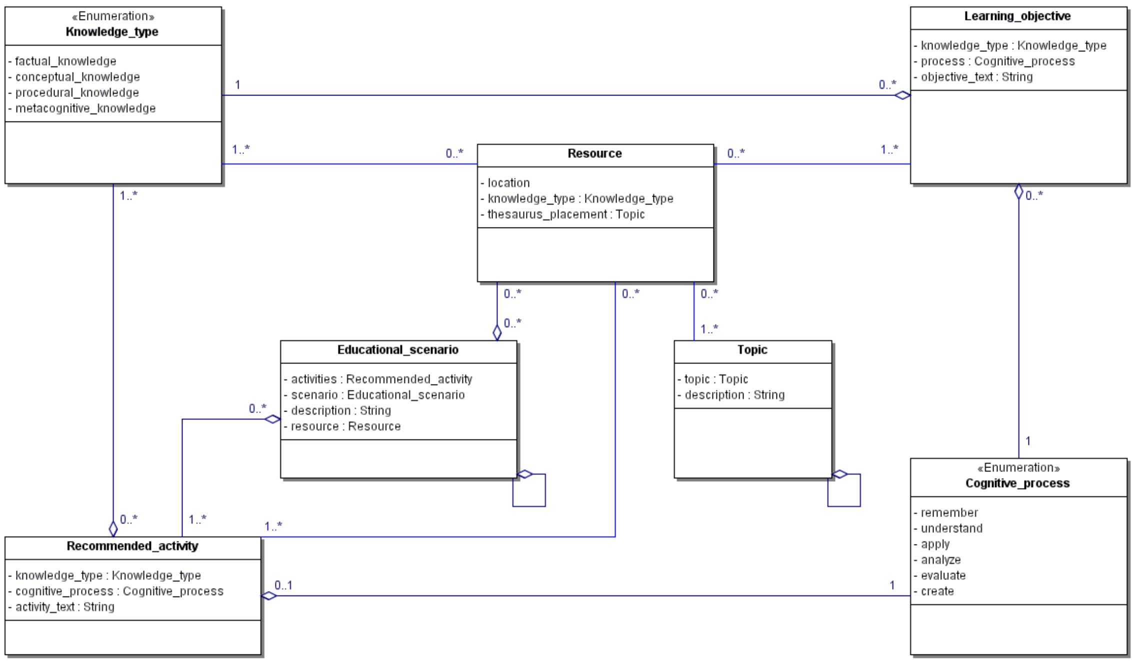

Fig. 5 Class diagram of the CampusContent model (by Sascha Bobrowski, Olaf Nowaczyk, Susanne Heyer)

Table 1 Anderson & Krathwohl Taxonomy (2001:28)

The Knowledge Dimension	*The Cognitive Process Dimension*					
	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge						
Conceptual Knowledge						
Procedural Knowledge						
Metacognitive Knowledge						

Table 2 The knowledge dimension of the Anderson & Krathwohl taxonomy including subtypes (2001:46)

Major Types	Subtypes
Factual knowledge	Knowledge of terminology
	Knowledge of specific details and elements
Conceptual knowledge	Knowledge of classifications and categories
	Knowledge of principles and generalizations
	Knowledge of theories, models, and structures
Procedural knowledge	Knowledge of subject-specific skills and algorithms
	Knowledge of subject-specific techniques and methods
	Knowledge of criteria for determining when to use appropriate procedures
Metacognitive knowledge	Strategic knowledge
	Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge
	Self- knowledge

Table 3 Sample counter for a resource displaying the matched knowledge type and cognitive process

The Knowledge Dimension	*The Cognitive Process Dimension*					
	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge	0	0	0	0	0	0
Conceptual Knowledge	0	0	0	0	0	0
Procedural Knowledge	0	0	1	0	0	0
Metacognitive Knowledge	0	0	0	0	0	0

Table 4 Strong correlations between knowledge types and cognitive processes

The Knowledge Dimension	*The Cognitive Process Dimension*					
	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge						
Conceptual Knowledge						
Procedural Knowledge						
Metacognitive Knowledge						

Table 5 Graphical output of dynamic metadata for a resource indicating its pedagogical potential

The Knowledge Dimension	*The Cognitive Process Dimension*					
	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge						
Conceptual Knowledge						
Procedural Knowledge						
Metacognitive Knowledge						