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Context Aware Reuse of Learning Resources

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Abstract: We propose a methodology for the reuse of contextualized learning content. The current reuse methodology requires context independent learning content and introduces a reuse paradox: "the most reusable objects are context-independent, while the best instruction is highly contextualized". We identify two aspects of contextualization: specialisation on the educational context the content is created in and for, and interconnection of different parts of the content. We argue that both aspects cannot be avoided completely and need to be addressed by a reuse methodology and reuse support technology. We analyse different aspects of context, context dependencies in learning content, and their role within the reuse process. We show how context aware reuse methodology can avoid a reuse paradox and infer novel requirements on a technical reuse support infrastructure.

1. Introduction

Building online learning content is demanding and cost intensive (Kerres 2001, Henderson 1998). Reuse of learning content promises cost reduction, increased quality and consistency. The question of appropriate reuse methodologies and technology for e-Learning content has been in the centre of interest in recent e-learning research. Standards for the description of learning objects by metadata such as Learning Object Metadata (LOM 2002), and for the exchange and execution of learning objects on different systems (IMS CP 2003, ADLNet 2001a, ADLNet 2001b) have been developed and are adopted by a wide range of e-learning products (cetis 2003). The current "object oriented" approach to reusing learning content is based on the engineering methodology of generalization, modularization, reduction of dependencies between modules and reuse of modules by composition (Henderson 1998, Seeberg 2003, Longmire 2002). We argue that this methodology does not perfectly suit the demands of instructional design on learning content. The requirement of modularization conflicts not only with traditional writing styles (Seeberg 2003), but also with instructional design theories demanding the interconnection of topics to be learnt (Whiley et al. 2003, Ausubel 1968). The requirement of generalization conflicts with the need for tailoring the learning content to the specific properties of the teaching/learning situation. Thirdly a methodology of creating courses by composition abstracts from the demand of necessary contextualization of reused learning (Wagner 2002, Baruque 2003, Whiley et al. 2003). A reuse-paradox is created: "the most reusable objects are context-independent, while the best instruction is highly contextualized" (ADL Co-Laboratory 2002).
After examining the current state of the art in reusing learning content, we analyse different aspects of context and context dependencies and discuss their role in the instructional design of learning content. Based on this analysis we present a reuse methodology which does not cause a reuse paradox, and infer requirements on reuse support systems for learning content. The paper concludes by a summary and an outlook of future research tasks.

2. Reuse of Learning Content: State of the Art

For the most recent and relevant reuse methodology in e-Learning the term "Learning Object Approach" has been coined. Various definitions and taxonomies exist to characterize different aspects of "learning objects" (LOM 2002, Whiley 2000, Longmire 2002, Polsani 2003, Friesen 2001, Clark 1998). Common in most of these characterizations is the goal of reusability. The learning object research focuses both on the instructional design of reusable learning content and on the definition of a technical reuse infrastructure aiming at retrieval support and interoperability. The basic observation is that traditional large, interdependent (monolithic) courseware is hard to reuse. The methodology for the design of *reusable* learning content is best characterized by the term "modularization" rather than the controversially discussed term "object orientation" (Friesen 2001, Sosteric & Hesemeier 2002). The central processes in the development of learning object based content are:

- *Decomposition*: Learning content is chunked down to small components – "learning objects" – which are possible reuse candidates (Henderson 1998, Rayindran & Venkatachary 2002).
- *De-contextualization* (Reduction of context dependencies): Learning objects are designed to be independent from each other, i.e. there are no technical and semantic dependencies between learning objects. Furthermore, learning objects should not be restricted for being used in a specific teaching/learning context. They should be generally applicable (Polsani 2003, Longmire 2002).
- *Description and centralized storage*: A learning object is described by metadata and stored in repository, which manages retrieval and access to the learning object. Ideally a learning object is reused by reference. When the

learning object is updated in the repository, the update is automatically propagated in each context of use (Seeberg 2003, Dhaief et al. 2001).

- *Aggregation*: Construction of larger content structures is based on a "lego" or "construction kit" metaphor (Bungenstock et al. 2002, Baudry et al. 2002). Suitable learning objects are retrieved from a repository and aggregated to build up course structures ("take and aggregate" approach).

The advantages of the learning object approach are obvious: by adopting a "take and aggregate" method courses can be built easier and faster or even automatically (Brusilovsky 1999, Hübscher 2000, Seeberg 1999), centralized storage and reuse by reference guarantees easy and consistent maintenance of learning content (Seeberg 2003), and the return of investment is higher when the same object is used in several contexts (Downes 2001, Henderson 1998).

3. Designing Reusable Learning Content – Possible Problems from a Pedagogic Perspective

Learning objects are developed *in* and *for* a context. The context the learning object is developed *in* we refer to as *authoring context*. The context, the learning object is developed *for* we refer to as *application context*. The *authoring context* comprises 1) other educational content within the learning application or document the learning object is embedded in, 2) the background, experience, styles and preferences of the authors regarding didactic strategy, content structure and presentation, 3) technical, personnel, budget and time constraints for the development of the content and other properties of the environment which the learning object is created in. The *application context* is the (indented or actual) pedagogic situation, the content is used in. Important factors of the application context are

- the properties of target groups such as heterogeneity, pre-knowledge, learning styles, and motivation
- the social context: role of staff and learners in the teaching/learning process
- the teaching/learning objectives,
- the course type (face-to-face, distance, blended) and teaching styles (expository, problem oriented)
- other properties of the learning environment such as technical infrastructure, time constraints and examination regulations (Kerres 2001, Koper 2001).

From a pedagogic perspective the development of learning content should aim at providing the best possible learning experience within the constraints of the authoring and application context. Instructional design theories stress the exact analysis of the application context before learning content is developed (Kerres 2001, Tennyson et al. 1997). However, even if learning content could be designed to be independent from the application context as for example (Polsani 2003) proposes, the characteristics of the authoring context would shape the learning content in a specific way. In the following we illustrate two major conflicts in developing reusable, modular, context independent learning content from a pedagogic point of view: specialization vs. general usability and modularization vs. interconnection.

Specialization vs. General Usability

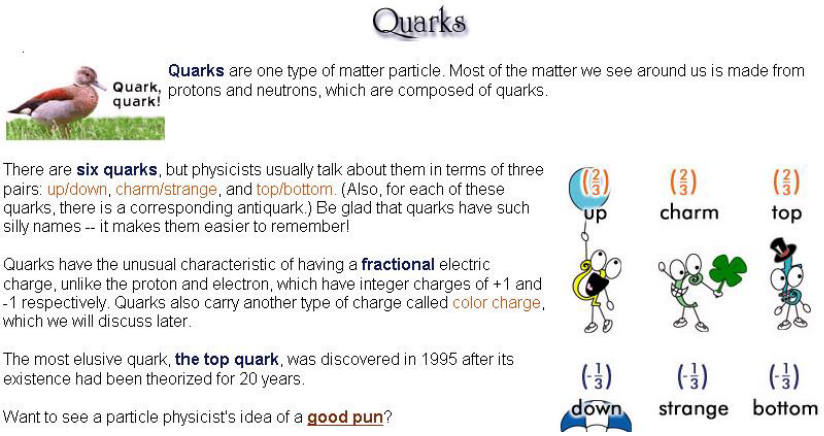

Figure 1: Screenshot from (The Particle Adventure 2003): use of funny illustrations

Reusable learning content is applicable in as many contexts as possible. However, pedagogically optimal learning objects need to be specialized on the application context. In contrast to mass media the learning content aims at modification of certain properties of the learner (behaviour, knowledge, attitude) from a starting state to a target state. Therefore, it is important to address the pre-knowledge and goals of the learner as exact as possible, otherwise parts of the learning content will either be irrelevant or incomprehensible for the learner.

An example of specialization is motivating content. The best way to motivate the learner is very different for different target groups and course types. For example, in a web-based course about particle physics for the general public it is appropriate to use funny cartoons or puns for motivation (fig. 1). In scientific settings these motivations might be misplaced or even confusing. Should this kind of humour be avoided in learning content for the sake of increased reusability as (Longmire 2000) suggests?

Modularization vs Interconnection

Learning content, in order to be reusable, needs to be modularized in independently usable chunks. Larger modules show a higher specialization on the application context because the larger a module the more likely a part of the module does not fit to the application context. Thus modules of reusable learning content should be as small as possible. Furthermore, in order to guarantee the independent reusability of single modules, technical and semantic dependencies to other modules need to be avoided.

From a pedagogic point of view content needs to be modularized to reduce the complexity of objectives in units of study. This helps the learner in building up knowledge step by step without getting lost in a too large amount of detail at a time. The design of the modular structure of the content in units of study, problems, learning steps, and activities (Koper 2001, Weitl et al. 2002) is driven by pedagogic considerations of the application context, such as experience, motivation, and attention span of the learner, complexity of the subject matter, and properties of the medium. The simple strategy "the smaller the better" is likely not to yield optimal results in all application contexts.

The second question regarding modularization of learning content is whether modules of a learning content can or should avoid dependencies to other modules. In larger units of content modules usually do not stand alone, but they have a certain pedagogic function in relationship to other modules. As an example a study task usually refers to resources needed to perform the task (Koper 2001). There are dependencies between tasks and resources: the task cannot be performed without the resources and a resource is irrelevant if it is not used in any learning task. Furthermore the modules are interconnected by mediating content (content, which refers to other parts of content) such as summaries, outlooks, repetitions, comparisons, and cross references. Mediating content plays an important role in expository learning (Ausubel 1968). Ausubel's subsumption theory stresses the importance of advance organisers and cross references to relate new knowledge to topics already learnt. Higher level objectives such as synthesis and evaluation (Bloom 1956) require that parts of learning content are not seen in isolation, but integrated into a larger picture by the learner. Mediating content can help the learner in this integration task.

4. A Context Aware Reuse Methodology

From our point of view, the answer to avoiding conflicts between reusability and didactic design of learning content lies in the shift of focus from a "reusability by design" approach towards a "support of reuse process" approach. The first step towards support of the reuse process of contextualized learning content is the analysis of the reuse process and the involved structures. In the sequel we describe a reuse methodology for context dependent learning content. Before we refine our model of context and context dependencies relevant in the reuse process.

Model of context and context dependencies in e-learning content

We understand context of a content fragment as all information and conditions in the authoring and application domain, which influence the design, the meaning, and the pedagogic effect of the fragment. As we have seen, we can distinguish between an authoring context (the environment a fragment is authored in) and an application context (the pedagogic environment a fragment is applied in for teaching). A third context can be identified – the learning context of the individual learner. Figure 2 visualises the different contexts and their relationship.

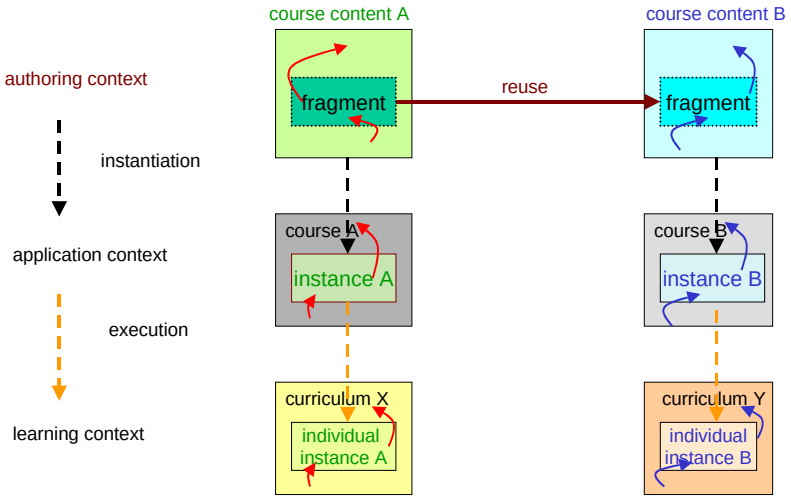

Figure 2: authoring, application and learning context

A learning object is usually authored as a part (*fragment*) of a larger *course content* in the *authoring context*. The course content is stored in a repository and may be inactive or used immediately in an *application context* (*instantiation*). This can be done by creating a *course* on a learning management system and putting the course content along with organisational information (time schedule, rooms, contacts) and support tools (chat, forum) online. Finally the course content is *executed* by the learner in an individual *learning context*. The *content instances* may be *individualized* (adaptation to learner profile, individual annotations) within the learning context. Reuse processes can occur at all levels of context (for example, different learners may share their annotations). In this paper we restrict our analysis to reuse processes in the authoring context.

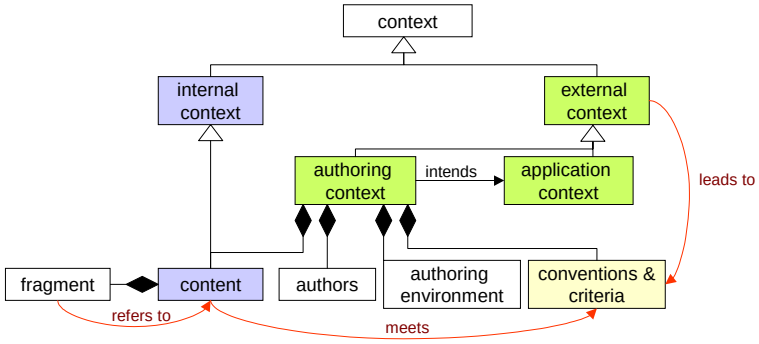

Figure 3: Model of entities relevant in the authoring context

Figure 3 visualises important entities of context within the reuse process. *Content* is created in a goal oriented way. Within the authoring context there are *assumptions* about the possible *application contexts*, which are created in the context analysis phase of instructional design. The *application context* can be described by standard models of an educational situations such as the "Berlin Model" (Heimann et al. 1972). Important parts of the *authoring context* are the *content* to be created, its *authors* (personal contributing in the authoring process), and the technical and organisational properties of the *authoring environment*. The content itself creates its own context referred to as *internal context*. External factors influencing the design and the applicability of learning content are referred to as *external context*. The external context leads to *conventions* and *criteria* within the authoring context. These criteria are an explicit or implicit specification of the target properties of the content typically represented in evaluation criteria and authoring guidelines.

Context dependencies in learning content can be classified as follows:

- *direct dependencies on the internal context*: direct dependencies are introduced by mediating content referring *directly* to one or more other fragments within the internal context. Examples of direct dependencies are cross references, summaries, outlooks.

- *indirect dependencies on the internal context*: a fragment does not directly refer to an other fragment, but the pedagogic effect of a fragment depends on the pedagogic effect of other fragments within the internal context. For example a learning task requires the presence of certain information resources within the internal context in order to perform the task. A fragment motivating the relevance of an objective requires that the objective is addressed by appropriate learning activities within the internal context. A rhetoric question to promote curiosity requires that the question is answered within the course of learning.
- *direct dependencies on the external context*: the pedagogic effect of a fragment depends on certain properties of the authoring or application context. Typical direct dependencies are specific requirements of the content on pre-knowledge, motivation and learning styles of the target group, the social environment (e.g. a certain learning activity requires the possibility of group work) and the technical infrastructure (e. g. a certain learning activity requiring the availability of an online discussion forum).
- *indirect dependencies on the external context*: indirect dependencies are introduced by the *conventions and criteria* valid in the authoring context. The conventions/criteria themselves are dependent on the external context. A typical criteria in scientific learning content is that terminology, mathematical, and graphical notations should be well defined and consistently used within authoring context. The convention that a concept *C* is represented by a term *T* is dependent on the authoring context. Other indirect dependencies on the external context are introduced by the chosen didactic strategy (problem oriented, goal oriented) or presentation style.

Internal context dependencies are caused by the requirement of interconnection on learning content. External context dependencies are caused by the requirement of specialization. As argued above, both kinds of dependency cannot be avoided completely and need to be considered when reusing learning content.

Reuse process of contextualized learning content

Given is an authoring context (*target context*) and a repository of not necessarily modularized learning content. The author is searching a reuse candidate for a certain authoring task. A typical reuse process of contextualized learning content can be organized in an *inquiry phase*, a *transformation phase* and a *storage phase*.

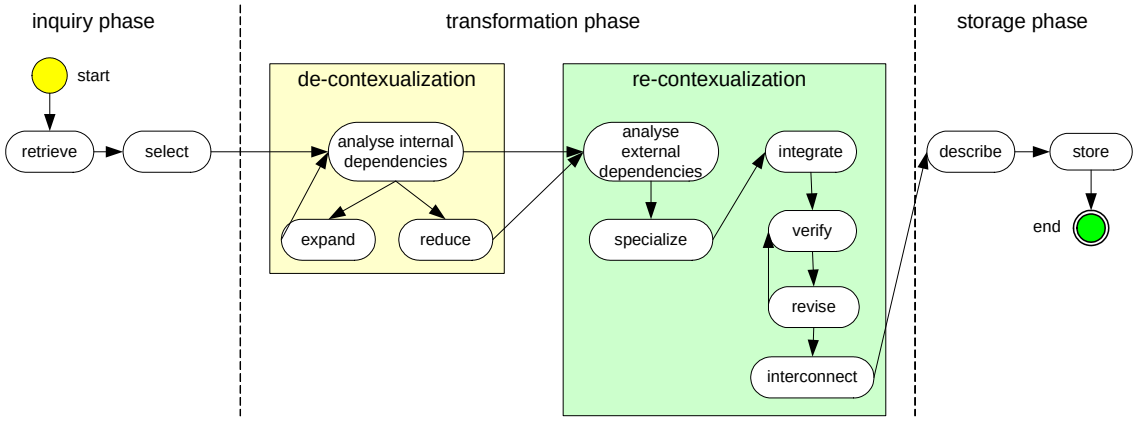

figure 4: Tasks within the reuse process of contextualized learning content

Inquiry phase: The author is looking for a suitable reuse candidate within the repository and poses a query on the repository by describing the *external context* (metadata) of the fragment sought-after. The repository *retrieves* a list of fragments, which meet the query, along with the *internal context* they have been authored in. The author browses the list and *selects* the most suitable fragment for the current authoring task.

Transformation Phase: As the selected fragment is presumably contextualized it is unlikely that the author can reuse the fragment as it is. Instead, it needs to be *transformed* to meet the requirements in the authoring context as close as possible. The transformation process can be organized in a *de-contexualization* and a *re-contextualization phase*.

The goal of *de-contextualization* is to isolate the selected fragment from its original *internal context* by resolving the disturbing *internal context dependencies*. The direct and indirect internal context dependencies of the fragment are

analysed. It has to be decided, if the dependency is satisfied within the target context. For example, if a learning task is reused it needs to be checked if the content of the target context contains all resources necessary to perform the task. If the target context does not satisfy a dependency it needs to be resolved. *Direct dependencies* can often be resolved simply by deleting referring parts from the fragment, i.e. by *reducing* the fragment to the non context dependent part. An alternative strategy is to *expand* the selected fragment with the destination of the dependency. For example if a selected fragment uses a specific concept, which is defined in the source context but is unknown in the target context, the fragment could be expanded by the definition of the concept. The expansion may introduce new internal context dependencies, which need to be analysed and resolved in the sequel. In the end of this iterative process the selected fragment should not have any *internal context dependencies* which cannot be satisfied within the *target context*.

The goal of *re-contextualization* is perfect adaptation of the fragment to the assumed *application context* and the seamless integration of the fragment into the new *internal context*. First, the *direct dependencies* on the *previous external context* need to be analysed and compared with the n*ew external context*. If there is a mismatch, the fragment needs to be adapted. For example if the language of the target group is not the same in the previous and the new context, the fragment needs to be translated. Examples and metaphors used in the fragment may be replaced by examples and metaphors which are more appealing to the new target group. After the *specialization* on the *new external context* the fragment is *integrated* at a certain position in the *new internal context*. The *indirect external context dependencies* (conventions and criteria) need to be *verified*. For example introduced mismatches in terminology or didactic structure needs to be discovered and *revised*. Finally the fragment needs to be *interconnected* with the new *internal context* by introducing new *mediating content* (cross references, comparisons) or by updating existing mediating content (summaries, outlooks).

Storage phase: In the *storage phase* the integrated content and its metadata *description* are *stored* or updated in the repository such that the content can be found and reused in other authoring contexts.

5. Discussion of the Methodology

The proposed methodology differs in following aspects from the current reuse approach:

- *retrieval in context*: possible reuse candidates are not retrieved in isolation but within their original internal context. The internal context helps the user to understand the fragment and to learn about pedagogic role of the fragment within its original context. The context a learning object is used in is sometimes a more valuable resource than the learning object itself.
- *de-contextualization on demand*: learning objects are not de-contextualized at authoring time, but at reuse time. The advantages are: existing, not explicitly modularized content does not need to be redesigned for reusability. The re-user can determine the granularity of reused fragments and does not need to depend on the modularity provided by the original author. Only the dependencies which cannot be satisfied by the target context need to be resolved. Finally, context dependencies can guide the author to further useful content within the source context.
- *modifying reuse*: systematic adaptation to the application context and integration into the internal context is part of the reuse-process. This allows for high optimization of the learning content regarding pedagogic considerations, but is problematic in the maintenance of learning content.
- *model character*: The presented methodology is a model of how contextualized learning resources are reused manually under *ideal conditions* (no time and money constraints). It serves as a theoretical framework to derive advanced features of future reuse support technology. It is unlikely that a context aware reuse methodology can be automated completely. Some decisions in selection, de- and recontextualization require a lot of background knowledge which is hard and expensive to formalize. Still, much can be done to support the author in the reuse process and thus to reduce the cost of a context aware reuse method.

Implications on Reuse Support Technology

Various requirements on the implementation of learning content and the functionality of future reuse support systems can be derived from the methodology described above.

- *retrieval in context*: the metadata of learning objects should contain pointers to internal contexts and descriptions of the external contexts they have been used in. Also, the system should be able to compare different contexts and give suggestions of suitable reuse candidates for a given authoring context without explicitly querying the repository (Ye & Fischer, 2002a/b).

- *de-contextualization*: learning content needs to be implemented such that it can be flexibly selected, expanded and reduced at reuse-time. Therefore, a very *fine granular selection* of learning content needs to be supported. *Internal context dependencies* need to be represented in learning content such that the system can determine if the dependency is satisfied within a *new internal context*. Content causing context dependencies needs to be *separable* from the rest of the content.
- *re-contextualization*: support of *re-contextualization* requires at least easy *modification* of the reused content. For support of *specialization* good models of *external context* and interdependencies between content properties and properties of the external context are required. Dependencies on the external context can be formalized as *pre-conditions* on the external context of a content fragment. A formalism for the representation and evaluation of these pre-conditions and a method for inferring them from content properties needs to be defined. Support of *integration* requires the representation of the *conventions* and *criteria* in a *formal specification* which can be verified automatically against an internal context. The support of *interconnection* requires a formalism to represent the necessary knowledge and interconnection rules to validate and generate mediating content.
- *storage*: modifying reuse of learning objects creates new learning objects, which are derived from original learning objects by some change operation. For *maintenance support* of learning content updates to the original learning object need to be propagated to the derived learning objects in a well defined and controlled way (*change management*) (Krieg-Brückner et al. 2003). A method has to be defined to integrate possibly conflicting update and reuse changes in reused learning content.

The feasibility, cost, and actual benefit of each of these features have to be investigated in future work.

6. Conclusion

Current reuse methodology abstracts from the requirement of specialization and interconnection of learning content. As a result, currently available e-learning technology introduces a reuse paradox: a conflict between the requirements of reusability and the requirements of traditional instructional design. We try to solve the reuse paradox by shifting our focus from "reusability by design" approach towards a "support of reuse process" approach. We analysed entities of context and their role in the reuse process: retrieve in context - select best matching fragment – de-contextualize from the previous internal context – specialize on the new external context – integrate into the new internal context – storage. We derived new challenging research problems to solve in supporting these reuse processes. Our future research on the pedagogic side will focus on empirical studies of interdependencies between content properties and properties of the different types of context. On the technical side we will examine knowledge representation formalism of the semantic web and the applicability of formal methods to represent and handle context dependencies as a first step towards a reuse support infrastructure for contextualized e-learning content.

References

ADL Co-Laboratory (2002). *The SCORM Implementation Guide: A Step by Step Approach,* Advanced Distributed Learning

ADLNet (2001). *Sharable Content Object Reference Model Version 1.2, The SCORM Content Aggregation Model*, www.adlnet.org

ADLNet (2001): *Sharable Content Object Reference Model Version 1.2, The SCORM Run-Time Environment*, www.adlnet.org

Ausubel, D.P. (1968). Educational psychology – A cognitive view. New York

Baruque, L.B., & Melo, R.N. (2003). Learning Theory and Instructional Design using Learning Object, *Learning Objects 2003 Symposium*, Hawaii

Baudry, A.,Bungenstock, M., Mertsching, B. (2002). Architecture of an E-Learning System with Embedded Authoring Support, *Proceedings of the E-LEARN 2002--World Conference on Educational in Corporate, World Conference on E-Learning in Corporate, Government, Healthcare, & Higher Education (ELEARN 2002)*, Montreal, Canada, 110-116

Bloom, B.S. et al. (1956). Taxonomy of Educational Objectives. The Classification of Educational Goals. *Handbook I. Cognitive Domain*, Longman, New York

Brusilovsky, P (1999). Adaptive and Intelligent Technologies for Web-based Education, *KI - Künstliche Intelligenz*, 13(4), 19-25

Bungenstock, M., Baudry, A., Mertsching, B. (2002). The Construction Kit Metaphor for a Software Engineering Design of an E-Learning System, *Proceedings of the ED-MEDIA 2002--World Conference on Educational Multimedia, Hypermedia & Telecommunications*, Denver, Colorado, USA

cetis (2003). Standards-compliant products directory, the centre for educational technology interoperability standards, http://www.cetis.ac.uk/directory (visited Dec. 2003)

Clark, R.C. (1998). Recycling Knowledge With Learning Objects, *Training & Development*

Dhraief, H., Nejdl, W., & Wolf B. (2001). Open Learning Repositories and Metadata Modeling, *Proceedings of the International Semantic Web Working Symposium, held jointly with HCI International 2001*, Stanford, USA

Downes, S (2001). Learning Objects: Resources For Distance Education Worldwiede, *International Review of Research in Open and Distance Learning*, 2 (1)

Friesen, N. (2001). What are Educational Objects. *Interactive Learning Environments*, 9 (3)

Heimann, P., Otto, G., Schulz, W (1972). *Unterricht - Analyse und Planung*, Hannover

Henderson, B. (1998). *The Components of Online Education: Higher Education on the Internet*, Univ. of Saskatchewan, Saskatoon, Canada

Hübscher, R. (2000). Logically Optimal Curriculum Sequences for Adaptive Hypermedia Systems, *International Conference on Adaptive Hypermedia and Adaptive Web-based Systems*, Springer, 121-132

IMS-CP (2003). *IMS Content Packaging Information Model, Version 1.1.3 Final Specification*, IMS Global Learning Consortium

Koper, R. (2001). *Modeling units of study from a pedagogical perspective.* Open university of the Netherlands

Krieg-Brückner, B., Hutter, D., Lindow, A., Lüth, C., Mahnke, A., Mehlis, E., Meier, P., Poetzsch-Heffter, A., Roggenbach, M, Russell, G., Smaus, J.-G., & Wirsing, M. (2003). MultiMedia Instruction in Safe and Secure Systems, *Recent Trends in Algebraic Development Techniques*, LNCS, vol. 2755, pp. 82—117, Springer Verlag

Lin, F. (2001): A Critique of Stephen Downes' Article, "Learning Objectives": A Chinese Perspective, *International Review of Research in Open an Distance Learning*

LOM (2002). *Draft Standard for Learning Object Metadata, IEEE 1484.12.1/2002*, Learning Technology Standards Committee

Longmire, W. (2002). Content and Context: Designing and Developing Learning Objects, *Learning Without Limits*, 3

M. Kerres (2001). *Multimediale und telemediale Lernumgebungen, Konzeption und Entwicklung*, Oldenbourg Verlag München Wien

Polsani, P.R. (2003). Use and Abuse of Reusable Learning Objects, *Journal of Digital Information*, 3 (4)

Ravindran, J.A., Venkatachary, R. (2002). Aggregation and Reduction: Two Design Approaches for Reusable Instructional Materials, *Proceedings of the E-Learn 2002 Conference*, Montreal, Canada

Seeberg, C. (2003). *Life long Learning - Modulare Wissensbasen für elektronische Lernumgebungen*, Springer-Verlag, Berlin, Heidelberg, New York

Seeberg, C. Steinacker, A., Reichenberger, K., Fischer, S., & Steinmetz R. (1999). Individual Tables of Contents in Web-based Learning Systems. *Proceedings of the 10th ACM Conference on Hypertext and Hypermedia.*

Shaw,S., & Sniderman, S. (2002). Reusable Learning Objects: Critique & Future Directions, *Proceedings of the E-Learn 2002 Conference*, Montreal, Canada

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 an Distance Learning*

Tennyson, R.D., Schott, F., Seel, N.M., & Dijkstra, S. (Eds.) (1997). Instructional Design: International Perspectives. *Volume I: Theories and Models of Instructional Design*, Mahwah, NJ: Erlbaum.

The Particle Adventure (2003). *The Particle Adventure, the fundamentals of matter and force*, Particle Data Group of Lawrence Berkeley National Laboratory, http://particleadventure.org/particleadventure/ (visited Dec. 2003)

Wagner, E.D. (2002). The New Frontier of Learning Object Design, *The eLearning Developers' Journal*

Weitl F., Süß C., Kammerl R., & Freitag B. (2002). Presenting Complex e-Learning Content on the Web: A Didactical Reference Model, *Proceedings of e-learn 2002 world conference on E-Learning in Corporate, Government, Healthcare, & Higher Education*, Montreal, Canada

Wiley, D. A. (2000). Connecting learning objects to instructional design theory: A definition, a metaphor, and a taxonomy. In D. A. Wiley (Ed.), *The Instructional Use of Learning Objects: Online Version.* (visited Apr. 2003)

Wiley, D. et al. (2003). Using O_2 to Overcome Learning Objects Limitations, *Learning Objects 2003 Symposium*, Hawaii

Ye, Y. & Fischer, G. (2002a). Supporting Reuse by Delivering Task-Relevant and Personalized Information, *Proceedings of 2002 International Conference on Software Engineering (ICSE'02)*, Argentina

Ye, Y. & Fischer G. (2002b). Information Delivery in Support of Learning Reusable Software Components on Demand, *Proceedings of the 2002 International Conference on Intelligent User Interface (IUI'02)*, Colorado