



MOBIlearn

**WP 4 – PEDAGOGICAL METHODOLOGIES AND
PARADIGMS**

THE OPEN UNIVERSITY

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**D4.2 - Best Practices for Instructional Design and
Content Development for Mobile Learning**

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Summary

This is a working document which is being updated and revised according to (a) the technical development of the MOBIlearn system, and (b) evaluation of user activities as they engage with it. It outlines issues surrounding the development of learning objects, and provides guidelines for technical development of content. The document is a companion document to D4.1 which identifies issues from the higher level teaching and learning perspective.

Document History

Version History

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[1.1]^{note} [First Review]

Summary of Changes

Version	Section(s)	Synopsis of Change
0.1	23.02.04	Initial version. Contents of sections 2,3,4,5,6,8,9 integrated
0.2	04.03.04	Section 4 integrated with a new LO definition
1.0	30.06.04	General Revision preparatory to submission; addition of content to Section 7; section 7 moved to Section 1 and amendments to subsequent section numbering
1.0	Cover sheet only	Closed – status changed from Final – Living to Final.

[1.1]^{note}

Note

Reviews after final document delivery (Version 1.0) to the project may or may not result in modifications to the document. If modifications post review are necessary, then the first version of the resultant document is 1.1.

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1. Object of this Document

This is a working document which is being updated and revised according to (a) the technical development of the MOBIlearn system, and (b) evaluation of user activities as they engage with it. It outlines issues surrounding the development of learning objects, and provides guidelines for technical development of content. The document is a companion document to D4.1 which identifies issues from the higher level teaching and learning perspective.

Its current status owes much to the technical input from Giancarlo Bo at Giunti Ricerca, for which many thanks are due. The full weight of the pedagogical perspective cannot be fully appreciated yet as empirical studies are still in progress. Therefore, at this time, the document has a largely technical thrust, supporting the development of the system and its content. In due course, input will be integrated from other partners and WPs 2, 3 and 4 which will reflect the user perspectives. There is also a link to documentation which is emerging from WP3 (D3.2). More authors will contribute at a later date. The final version will not be available until the end of the project.

The history of D4.2 has been problematic, partly because it attempts to address an issue which is acknowledged in the literature to be pretty intractable – i.e. the nature and structure of learning objects, from both a pedagogical and technical perspective, and the role of content, and its presentation, in learning. Furthermore, the concerns that a document such as this needs to address permeate several workpackages, but each has a different perspective on priorities for resolution. This has provided a challenge to partners, one which we are still meeting, but the outcomes will be of great interest and significance to the research community.

2. Introduction

In this document we tackle the issues related to instructional design and content development within the framework of the workpackage on pedagogical methodologies and paradigms. This is not an easy marriage of topic areas, since it interfaces high-level theoretical issues with practical technical issues which allow design to move forward. It is clear from the literature in this area that there are often gulfs of understanding, and use of language and terminology, between the more user-oriented perspectives and the technical views. This is not unique to MOBIlearn.

In order to cope with this spread of concerns, the first section outlines the higher level issues, and identifies the philosophical stance of the project toward pedagogy and instructional design. This discussion then moves toward the use of learning objects within the project. Subsequent sections then develop an increasingly detailed and technical specification of content. This latter part outlines the principal requirements of contents that are compatible with the aims and objectives of the MOBIlearn Project. These are not intended to be definitive, but instead aim at defining a desirable level of pedagogical and technical compliance that would benefit both the project and content developers in general.

3. Pedagogical Specifications

The advent of mobile devices to support learning has challenged educators in many ways, not least how to devise pedagogically sound practice and theory to deploy them. Sariola et al (2001) suggest that a technology-based definition of mobile learning is not sufficient – i.e. defining m-learning as that learning which is taking place through the use of mobile devices does not have educational relevance per se. The issue, rather, is that mobile learning is defined by virtue of the fact that it is the learner who is mobile, and is not defined by the devices they choose to use. In this sense, books are archetypal mobile learning devices that we have used for centuries. Books make access to content and teaching discourse relatively easy¹ and ensuring that learners have the literacy and study skills needed to exploit this has occupied educators for many years.

But mobile devices also provide a new challenge to educators – they inherit the potential for interactivity that goes with computers and digital media, and that for adaptivity of content and interface. They also provide means of access and communication both between learners and peers/tutors; and between learners and digital resources. Pedagogically, then, how best to make use of these characteristics? Unfortunately the research literature does not report straightforward solutions to this question. Kinshuk (2003), in discussing adaptivity points out:

Although various research groups are exploring the potential of adaptation in mlearning, lack of research on some issues still blocks progress. These issues include mediation between the academic institutional requirements and personal learning constraints, profiling and personalization features needed for appropriate mlearning and educational pedagogies focusing on m-learning environments.

Before entering into further discussion of learning objects, there is an issue to address around the role of content in learning, and how this impacts upon pedagogy and, in turn, on the design and intended use of learning objects.

3.1 Content, Learning and Learning Objects: A Debate

The phrase ‘content is king’ has begun to lose its lustre as the debate around appropriate pedagogy or instructional design for on-line learning has developed in recent years. In a fascinating article by Nathan and Robinson (2001) the authors stress that identifying a pedagogical stance emerges from specifying a view on the nature of learning. They suggest that by identifying a separation between the instructional agent and the learner agent, and deciding where you think agency lies, your view of appropriate pedagogy (and instructional design) will vary – does the agency lie with the instructor or the learner?² In a traditional transmissive view of learning, where the agency lies with the instructor (i.e. the teacher constructs the

¹ The history of the UK’s Open University provides many examples of how to incorporate explicit teaching within texts for learners at a distance, and often on the move. OU students have been ‘mobile’ learners for many years.

² ‘Agency is the instrument by which one structures one’s environment and situation to meet one’s goals. The importance of agency with regards to pedagogy is that locating agency within the instructional agent or within the learner agent alters the way we think about a learning environment. [This] has dramatic influence over the practices (pedagogy) one designs ...’ Nathan and Robinson 2001

learning environment and specifies what students should do and how they should do it), the learning process is relatively passive and reactive, while the instructional agent is relatively active and causal. The fundamental dynamic is on the part of the instructor to transmit high quality information and content. The important concerns in this view of learning, then, are (a) on constructing a suitable learning environment containing all that is needed to learn; (b) on effective transmission processes, and (c) the quality of the presentation of information. These would be integrated with feedback as to the learner's progress through the material.

Alternatively, at the other end of the spectrum, where the agency for learning lies with the learner, learning is viewed as an active, constructive process. Learners are seen as creating new knowledge for themselves, extracting information from the environment (that they have constructed) as they see fit, and meshing it with existing knowledge. This 'constructivist' mode recognises that learning agency lies with the learner, and he or she will seek out information as and when needed. Information may come as much from colleagues and co-workers as it may come from instructors or 'content'. In the digital environment, this has led to some claims for radical pedagogies where courses begin with only the communicative facilities amongst students in place, with no content at all. Learners decide for themselves what content to bring forward, and how to relate to it (e.g. see Barab, Thomas and Merrill, 2001), and the tutor role is more of a facilitator than instructor. Literacy models of learning and pedagogy also problematise the role of content, arguing that learning (particularly for adults) is more about challenging texts than assimilating them (see Lea, 1998).

Typically, higher education deals with traditionally designed content-rich courses of the first type, where students are expected to come to grips with a substantial body of knowledge which is presented to them by the instructor. The potential for learning objects in this environment is circumscribed, though mainly by institutional concerns often driven by the assessment process:

Once the course designer is taken out of the process of aggregating course content and there is no one to intervene as the "glue" holding a course together, it is obvious that the LOs themselves must carry the weight of the whole course edifice. There is little enthusiasm or call within universities to pursue this line of development. The extent to which it is possible to design LOs that lead to satisfying, effective and high-quality learning experiences without this expert intervention is seriously questioned by most academics. The notion of reuse and repurposing of materials is a far more acceptable practice in higher education as it provides scope for the course designer or course team to benefit from some efficiencies whilst offering latitude for creativity and expert input.

The higher education sector is interested in LO development from the perspective of reuse and repurposing learning materials. Textual explanations, graphical and video material developed for one course ought to be reusable for another course in a different discipline with consequent saving of resources. Courses designed from the beginning with very small modules ought to be easily re-shaped and re-sized for different markets. Universities at the forefront of LO development are designing templates and other systems to support academics in the preparation of learning material geared to reuse.

Mason and Rehak, 2003

There are circumstances, though, in which learning objects do function well. Mason and Rehak (2003) make the distinction between education and training in relation to learning objects:

While the mechanisms for tagging, retrieving, sequencing and presenting a course comprised of LOs are problematic enough in themselves, the business of conceiving of a course as a collection of independent LOs is utterly rejected by many educators. But aggregating content in this way is an acceptable approach in training where it is particularly effective for teaching rudimentary skills, or for competency- or performance-based subjects where the emphasis is on what people want or need to know, not on what there is to be known. [...] In this scenario, learners indicate their personal parameters, needs, background knowledge, etc. and courses are created automatically from the database of LOs. A number of very significant implications about the nature of LOs arise from this scenario, not the least of which is the nature of the instructional design that underpins the learning experience.

And hence back to the debate indicated above. The question, then, for the MOBIlearn project is what kind of learning do we envisage typical users to be engaged in, what models of learning do we want to promote, and from this follows the kinds of learning objects we want to develop – or even whether we need them at all?

3.2 Learning within MOBIlearn

In D2.1 for this project, 'User Requirements', we adopted the socio-cognitive engineering method (Sharples 2002b) as a user-centred design approach. Sharples et al (2002a) outline a theory of use as part of that method to inform system design, built around the concept of contextual lifelong learning, in which the stance on learning is articulated:

We can summarise contextual lifelong learning in terms of "3 C's" of effective learning: *construction*, *conversation*, and *control*. Successful learning is a constructive process (Brown & Campione, 1996) that involves seeking solutions to problems and relating new experiences to existing knowledge. Central to learning is conversation, with teachers, with other learners, with ourselves as we question our concepts, and with the world as we carry out experiments and explorations and interpret the results (Pask, 1976). Learning is most successful when we are in control, carrying out an active and continuing cycle of experimentation and reflection (Kolb, 1984). A theory of learning which combines these aspects within an all-encompassing framework is Pask's Conversation Theory (Pask, 1976).

Conversation Theory is an elaborate and difficult construct that spans epistemology, educational technology, and cybernetics. It describes learning in terms of conversations between different systems of knowledge. Pask was careful not to make any distinction between people and interactive systems such as computers – with the great advantage that the theory can be applied equally to human teachers and learners, or to computer-based teaching or learning support systems.

We are, therefore, committed, as a project, to a constructivist paradigm, which has implications for learning objects and content. Elaborating this, within a Paskian framework, Sharples identifies a potential role for the computer, which could be to take the place of the teacher:

That is traditional computer aided instruction, and the difficulty is that it only covers part of the conversational space. The computer can hold a limited dialogue at the level of actions: "look here"; "what's this?"; "do that", but is not able to reflect on its own activities or its own knowledge. And because it cannot hold a conversation at the level of descriptions, it has no way of exploring students' misunderstandings or helping them to reach a shared understanding. [...]

Alternatively, the technology could provide an environment in which conversational learning takes place, that enables conversations between human learners. Networked computers can extend the range of activities and the reach of a discussion, into other worlds through games, software models and simulations and to other parts of this world by using the computer as a means of communication, through phone, email and computer based discussions. [...] The technology provides a shared conversational learning space. The main implication of this Theory of Use for design of personal learning technologies is that it suggests a system image based on support for multiple conversations, as opposed to one derived from learning as the transfer of knowledge. Neither a "classroom" nor "library" metaphor evokes learning as conversation.

This second role for the technology, then, must be a primary concern for MOBIlearn. Mobile devices are not large content delivery tools - they facilitate communication and conversations, and can provide short bullets of useful information. Furthermore, our pedagogical approach (sic) will not require the delivery of large content objects. However, consistent with a constructivist perspective, in which the learner has agency, if a learner wanted to access a large body of knowledge, he or she would be free to do so, since it is the learner that is mobile – if they have access to computing resources such as lap-tops or desk-tops in the environment, the mobile components should freely allow transfer of activity to them, and back again. As communication tools, mobile technology can stimulate reflective thinking and support it through linking to communities or groups of learners, even tutors, or the web, with its myriad resources available for download.

We need more information about the ways in which adult learners organise their informal learning, and studies are currently underway to evaluate this. They will be reported in D4.4 'Longitudinal Studies of Informal Learners'.

The logical consequences of this is that learning objects we construct for transfer by mobile devices should be of fine granularity, so they can easily and quickly be communicated, read and ingested. Anything that requires more than a few minutes of sustained reading is unlikely to be optimal (though all of this is subject to empirical evaluation, so can only be heuristic, not definitive) so information which spans wider reading times must be broken down to make it more digestible (hence the granularity issue). If we wish to point users at more substantial on-line resource, this should be achieved by the use of urls.

3.3 Learning Objects for MOBIlearn

Notwithstanding the debate that continues in this area, we have to make progress within the project. This has been achieved through the development of scenarios. We designed the scenarios to represent various kinds of activities within a constructivist approach. These are summarised in relation to content as follows:

3.3.1 The Health Scenario

The Health scenario is essentially a series of interactive exercises for First Aiders to support their skills and knowledge, and its refreshment over time. The First Aiders sometimes engage as individuals, sometimes as a group, interacting with peers and with the tutor. There is relatively little content, some of it based entirely around question and answer activities, with supporting information and images as necessary. The priority will be on demonstrating interactivity rather than richness of content media. Users also need to be able to upload their own content, and share with others.

3.3.2 The MBA scenario

The MBA scenario is concerned with providing support for collaborative working and learning. In this case the technology is the most important feature. Content is reference material copied from lectures and so on. From a WP3 point of view the task here is to format existing content in a way which is consistent with its original design but which is accessible on a mobile device.

3.3.3 The Museum Scenario

Finally, the Museum scenario is concerned with providing information to help users develop their understanding of the subject they are viewing. This is where we must put most effort into use of rich media. It is important here that we have a generic structure into which we can drop different sets of information for different locations.

From the pedagogic point of view, in two cases (Health and MBA) we have an external (human) tutor or teacher guiding the process of learning, but once within the activity, learners are encouraged to interact and collaborate with other students. The overhead on content rich learning objects is therefore light. However, in the Museum scenario we do need to use learning objects, with the full richness that digital can provide, and therefore design effort must go into developing these. Issues associated with this are discussed in later sections.

3.4 Discussion

This section has outlined the overarching theoretical background to the issue of pedagogy, learning objects and content in the MOBIlearn project. A great deal more information needs to be gathered to establish guidelines for the development of instructional design in the mobile domain, particularly with adult learners engaged in informal lifelong learning activity. There is little in the literature at the present time that goes beyond reporting of case studies – these are interesting, but the evidence base is still fluid and inconclusive. The empirical work we are conducting within the project will feed into this document further, in due course, providing evidence regarding the actual practice of adult learners, and the ease with which they use

mobile devices and the MOBIlearn system. At that point, pedagogy can be evaluated, and recommendations formulated.

We now shift gear to focus on a much more pragmatic view of learning objects which will take us into the technical arena. In the following sections we identify specifications for learning objects focusing on content delivery. As the project develops we will need to shift this focus to issues associated with facilitating communications and adaptivity. In particular, we will need to develop a pedagogic rationale for adaptation.

4. What is a learning object?

A learning object can be defined as a structured, standalone resource that encapsulates high quality information in a manner that facilitates learning and pedagogy. It has a stated objective and a designated audience. It has ownership and associated intellectual property rights. As such, its content shall remain unchanged in the process of converting the resource into a learning object. The following are some formal definition of Learning Object:

"Any entity, which can be used, re-used or referenced during technology supported learning." (IEEE Learning Technology Standards Committee - LTSC)

"An object or set of resources that can be used for facilitating intended learning outcomes, and can be extracted and reused in other learning environments... the term has recently been associated with electronic learning resources that can be shared in multiple learning environments" (S. Mills "Learning about Learning Objects with Learning Objects",

http://www.alivetek.com/learningobjects/site_paper.htm)

"A learning object is a small, reusable digital component that can be selectively applied - alone or in combination - by computer software, learning facilitators or learners themselves, to meet individual needs for learning or performance support." (C. Shepherd, "Objects of interest", <http://fastrak-consulting.co.uk/tactix/features/objects/objects.htm>)

Within the MOBIlearn Project the following definition has been adopted:

"A Learning (Information) Object is a reusable self-contained digital entity, with embedded metadata resources, that might interact with other objects, encapsulate other resources (information instances), in an interconnected environment."

Starting from this definition, a "LO definition matrix" has been developed whose aim is to help the owner evaluating quickly whether a digital entity meets or not the given definition. Below you can find the matrix:

	Reusable	Self-contained	Digital	With metadata	Interacts with other objects	Encapsulates other objects
CONTENT						

				Yes/No	Standard		
Content1	✓	✓	✓	✗	---	✗	✓
Content2	✓	✓	✓	✓	IEEE LTSC	✓	✗
... ..							

Opinions of concise definition differ, largely due to the difficulty posed by the level of granularity.

In general, a Learning Object must be:

- **Reusable:** The main idea of Reusable Learning Objects (RLOs) is to break educational content down into small standalone chunks that can be reused in various learning environments, in the spirit of object oriented programming.
- **Standalone:** Like Lego, RLOs are small standalone, reusable components - video, demonstrations, tutorials, procedures, stories, assessments, simulations, case studies, HTML/text pages, etc that can be assembled to provide resources for education and training.
- **Discoverable:** Objects must be able to be found. Learning Objects must be tagged with appropriate descriptive metadata in order to be identified for the purpose they are to be put. Whilst the technical description of objects is being addressed via the various metadata schemas that have been developed, there are increasing calls from educators for the metadata schemas to improve the pedagogic description of learning objects.
- **Granular:** Objects have a defined level of granularity which means they can stand alone as single items or be combined (aggregated) with other objects to form larger instructional units.
- **Interoperable:** Objects must be interoperable that is: content from multiple sources must work with different learning systems. In order to do this they must be designed to standards.
- **Instructionally effective:** In order to be defined as a Learning Object there must be some intrinsic instructional value. A Learning Object is not just a Knowledge or Information object.

4.1 Pros and Cons of Learning Objects

The pros and cons of using learning objects are summarized in the following table.

	PROS	CONS
Production Costs	By properly breaking content into learning objects, different parts can be maintained and updated separately. If a suitable learning object can be found, a new one does not need to be created. These are costs savers.	Changing to a learning object approach from a "self-contained system" approach involves retooling and retraining costs.
Flexibility	As more and more standards-based learning objects become available, increased choice	Using standards-based learning objects restricts the scope of learner

	will translate into more flexibility for designers.	information that is accessible by content if total interoperability is maintained*.
Pedagogy	Learning objects fit nicely into many ISD theories. Instructional templates can be created with slots for specific types of learning objects. Learning objects may encourage designers to operate in more disciplined ways with a positive effect.	Restrictions on learner information available could restrict pedagogical approaches. Approaches using lengthy discursive material may not benefit from the use of learning objects.
End User Cost	The learning object approach prevents consumers from being locked in to specific systems. As standards take hold, the market for content will take on more of the properties of a typical consumer market with lower costs and increased choice.	The cost of converting existing content to a learning object approach may be significant
Industry Support	All leading system vendors and content producers are supporting SCORM and other standards that are based on or that complement a learning object approach.	Realistically, it is twelve to eighteen months between the time the vendor community adopts an approach and the time products that implement the approach are available.

5. Developing Learning Objects

The success of the Learning Object strategy depends on a development process that is carefully thought out and methodically executed. The planning and production rests on two processes, *conceptualization* and *collaborative development*.

5.1 Conceptualization

Conceptualization is a key phase that lays the basis for success of the Learning Object strategy. LO modeling requires a double vision: on the one hand, a global understanding of curricula to conceive content object as part of larger whole, and on the other, a micro vision to create content as stand-alone information for it to function as reusable object. With this comprehensive visualization it is possible to achieve a maximum rate of reusability.

Content experts in the implementation of this framework should proceed in three steps:

1. Select a topic or theme in a discipline or that spans across different disciplines.
2. Identify different levels and depths the topic is treated in the discipline. This will provide an intensity map where ranges of depths, from the lowest to the highest level of complexity, are mapped.
3. Design Learning Objects in such a fashion that a combination of them can be used for each level of instruction.

5.2 Collaborative development

The information space opened up by the recent technological developments is the site of production, circulation and consumption of knowledge modules: the reusable

Learning Objects. The space of the Information Age is located in the interconnected global network of computers. The programmers who write the code for the operation and interconnection of these computers create the information space; the graphic designers design and develop interface to facilitate the management, input, and manipulation of information located in the space; and the subject matter experts provide the ideas/concepts stored as information bits. Since the role of experts from all three fields is crucial for the successful development and use of Learning Objects, the creation should be a cooperative and closely aligned process wherein the experts use each other's knowledge as strength for creating ideas, make them visually compelling and store them in databases for access and manipulation. Furthermore, as the nature and functional requirements of knowledge are ever-changing in the knowledge economy no single academic or a subject matter expert can generate a total knowledge adequate to the tasks. Therefore knowledge experts should develop only 'events' of knowledge that can combine with other 'events' to develop into a 'program' on demand. This 'events' approach should be seen as strength instead of weakness, since it is a contribution to a collective knowledge that is flexible, functional and adaptable.

6. Standards and Specifications for developing Learning Objects

As Learning Object development is a collective enterprise among the programmers, graphic designers, and subject matter experts, a standardized approach can accelerate and establish efficiency in the Learning Object strategy. It is important that the developers agree to a set of specifications for development of Learning Objects covering such areas as technology, editorial requirements, and stylistic considerations. A commonly agreed upon standards will enable genuinely sharable and reusable content objects, without which we will revert back to current iterations: static WebPages.

6.1 Technical standards

The technical specifications should address the interoperability of Learning Objects and the physical structure to facilitate easy manipulation of the elements. The success depends on the flawless execution of Learning Objects in all operating systems and delivery media. What is crucial for achieving interoperability is the selection of language for producing Learning Objects. The language should be chosen with the future in view, that is we should not attempt at making objects compatible with all earlier generation technologies, instead we should focus on the next generation technology. Extensible Markup Language (XML) is ideal for achieving both these purposes since it is being endorsed as the standard for all future applications. Additionally, separation of structure, content and presentation, which is the fundamental logic of XML, will allow the flexibility required for deploying and manipulating the Learning Objects.

6.2 Editorial requirements

Every discipline has its own discourse and rules of construction of its discourse. Subject matter experts of a discipline should agree before hand on editorial standards to ensure the consistency of language across the Learning Objects. Similarly a common terminology should be created for referring to concepts in a discipline. In order to accommodate the requirements of Learning Object strategy and the individual stylistic preferences, a Learning Object can have a glossary that explains the terminology used in a Learning Object and cross-references with other terms used in the discipline to refer to similar concepts.

6.3 Stylistic considerations

Appearance and style are extremely important for an effective presentation of Learning Objects. The developers should draw up specification for use of colour, fonts, and layout of images and text. These structural elements should be consistent across Learning Objects so that they can be easily combined to for instruction. Since XML separates content, structure and appearance, the stylistic considerations can be excluded from the domain of subject matter experts. Because of the flexibility offered by XML, the same style sheets can be used for different contents without additional development, and each can be modified without affecting the other. An ideal situation would be to develop several interface and stylistic environments that are user-controlled, which would enable the user to choose the most suitable form of interacting and exploring the knowledge.

6.4 Some broad Learning Object development specifications

- Consistent use of language and terminology within a topic area. Consistent terminology allows discrete objects to be easily disassembled and reassembled, retaining consistent meanings that are reflected in contextualising reference documents.
- Presentation of information in easily accessible and comprehensible formats. For example, detailed or technical information may be better presented in tables, bullets, or columns rather than sentences or paragraphs.
- Presentation of information for on screen consumption. As LOs will most often be accessed and used onscreen, standard techniques of Web content design should be followed. For example, dense text should be chunked into smaller units.
- Nonsequentiality of information across objects. Information needs to be free-standing and easily adapted to multiple contexts. This means there should be no backward-forward referencing across objects (such as references to previous chapters). There are a number of techniques for handling this requirement, such as the use of mini summaries that provide just enough context to introduce a concept, and the use of tagged context "wrappers." Of course, within an object it may be necessary to present information sequentially. For this reason, it is necessary to determine the granularity, or size, of the smallest object before beginning development.
- Uniformity of editorial tone across objects. Unless an object is specifically tagged as an introduction or conclusion, it should not have the editorial tone of an opening or a conclusion.
- Use of keywords in searchable elements. If certain keywords will be used to link specific content areas, searching capabilities will be improved by actually using the keywords in titles and searchable elements, such as tables of content and indexes.
- Use of language and content appropriate for a broad audience. For an object to be reused with minimal manual customization, the content needs to be appropriate for a broad audience. Regional terminology or audience-specific humor may not be appropriate. If colourful language or humor are desired when delivering the object as part of an engaging learning experience, these components are better added at the contextual level (and can be part of the personalization of learning content).

7. Technical Specifications

The aim of the following subsections is to provide an overview of the technical specifications to be taken into account when creating Learning Objects, both in general and for mobile applications. Different categories of specifications have been considered:

- Media specifications
- Output device specifications
- Interoperability specifications
- Accessibility specifications

7.1 Media Specifications

There are hundreds of file formats for representing media online or in print. Formats may be proprietary or non-proprietary, native to one particular software program or useable in a number of programs, and each has its own characteristics, making one "better" than another for its desired use. In the following sections the formats most commonly used for representing digital media assets of different types are briefly described, with their pros and cons.

Although the list of media described in this document is not definitive, it is the interest of learning objects developers to use technologies and formats which are commonly found on a range of browser-based systems. The use of many minor third party plug-ins is discouraged, since they might be problems in downloading or installing them. In general, the use of "open standards" formats should be preferred.

Another important rule, especially when designing and developing LOs for mobile applications, is: "smaller is better"! Anything being conveyed through the MOBIlearn system, notwithstanding the available run time adaptation capabilities, could present something of a "bottleneck" when the file size of a media asset (usually a video or audio clip) being displayed is large.

The four basic media-asset types are still images, audio, video and text pages. Since not all file types are optimal for viewing in all browsers on all operating systems, the following table provides a minimum set of the most reliable file types. These formats should be supported in almost any device configuration.

Text	Images	Video	Audio
HTML (Web page) = .htm or .html Text [Only with Line Breaks] = .txt	GIF = .gif JPEG = .jpg	QuickTime = .mov MPEG = .mpg AVI = .avi	Wave = .wav

7.1.1 Text

Format	Support	Uses	Advantages	Disadvantages	Bitrate	Standards
ASCII *.txt	Any text editor or word processor will open it, the most simple of which are Notepad or SimpleText	Common format for text files in computers and on the net; can be written in ASCII but saved as another type	Extremely small file sizes	Limited formatting capabilities (basically spaces, tabs and returns) and character set	128 possible characters represented by 7bit binary numbers	American National Standards Institute

DOC (Microsoft Word Document)	Microsoft Word, but can be opened by WordPerfect and other higher-end word processing apps	Word processing	Great flexibility in designing the look of a document from varying margins and indentations to tables and bullets	If pictures are included, they are embedded rather than linked, increasing file size		Microsoft / Corel
EBCDIC	IBM OS/390 systems	Text files for IBM S/390 servers; corporations use for and databases.	Supports more characters than ASCII; most common alternate character code	IBM's PCs and workstations don't use it, nor do other OSes; proprietary	256 characters represented by 8bit binary numbers	IBM
HTML (Hypertext Markup Language)	All browsers support HTML, though the advanced features are implemented differently in each and provide non-standard extensions	For view in internet browsers on the World Wide Web, though can be viewed offline	Allows a great deal of control over the look and layout of a document, including animations (dynamic HTML) and interactivity; can combine several computer languages seamlessly; pictures are linked to rather than embedded	In order to take advantage of all the capabilities, learning the coding language is necessary - a WYSIWYG editor will not do it all; older browsers do not support all tags		HTML 4.0 by the World Wide Web Consortium
OEBPS (Open eBook Publication Structure)	Used by a variety of electronic publishing systems and reading devices	Based on XML, HTML, CSS, and Unicode, among others, to define content, structure, and presentation of eBooks	Can embed rich media but there must be an alternate version (either XML, CSS, JPEG, or PNG) in case the device cannot read it; incorporates accessibility features from HTML; non-proprietary			Open eBook Publication Structure 1.0.1 maintained by the Open eBook Forum
RTF (Rich Text Format)	Can be opened, edited, and saved using MS Word	Allows for more control over the look of the document than ASCII	Since RTF uses ANSI, PC-8, Mac and IBM PC character sets, you can exchange text files between different word processors and different operating systems	Not as much control as MS Word and WordPerfect		RTF Specification
Unicode	NT and Win2000 systems; required by modern standards such as XML, SQL, etc.	Documents to be distributed to users on multiple platforms and countries	A unique number for every character, independent of platform, program, or language - the text will display correctly		34,168 characters in 24 languages	Unicode Worldwide Character Standard, Version 3.0
WPD (Word Perfect)	Windows only	Word processing	Supports hyperlinks and watermarks, HTML, CSS, XML, SGML; customizable macros	Proprietary		Corel
XML (Extensible Markup Language)	Opera browser has most complete implementation, DocZilla has even more, but is still in the alpha phase; MSIE 5.5 and Netscape 6 support also	Used on the Web, but can store any structured info	Non-proprietary; can design own document types (more control); removes complexities of SGML (Standard Generalized Markup Language) while retaining flexibility; more linking capability than HTML			SGML approved by International Standards Organization; XML specification 1.0 approved by World Wide Web Consortium

7.1.2 Images

Format	Support	Uses	Advantages	Disadvantages	Bitrate	Standards
Bitmap *.bmp	Browsers, various image viewing and editing programs (freeware, shareware, and proprietary)	Works well cross-platform	Flexible image format	Very little is compressed leaving large files	1 bit to 24 bits-per-pixel color data	Microsoft
GIF (Graphics Interchange Format) "jif"	All browsers, most image viewing and editing programs - low to high-end	Images with broad areas of flat color such as comics or logos	Interlacing; transparency; compression ratio of 4:1 to 10:1; lossless of 256-color images; animated GIFs; palettes	Vertical patterns are not converted well; posterization may occur if the color-depth is too low	8 bits-per-pixel	GIF89a; Unisys retains royalties

JPEG (Joint Photographic Experts Group) "jay-peg"	All browsers, most image viewing and editing programs - low to high-end	Photographs, or any image with transitional tone	Doesn't prejudice how many colors to use, displaying a truer image on any computer; up to 100:1 compression; progressive display	Image quality is compromised with greater compression, resulting in artifacts; doesn't handle straight edges or text very well	24 bits-per-pixel color data	IS 10918-1 (ITU-T T.81)
JPEG 2000 *.jp2	The W3C is not yet behind it, but there are a number of other projects trying to increase its support	Web images, pre-press, medical imaging, security	All of the advantages of JPEG; lossy or lossless compression; security features like watermarking; wavelet compression; Regions of Interest coding	Limited support	Variable, up to 24 bits-per-pixel	Joint Photographic Experts Group; Migrator 2000 developing Intellectual Property Right protection, access control, and more
MNG (Multiple-Image Network Graphics) "ming"	No browser integration yet, but since the W3C is behind PNG it is likely not too far in the future	It is the animated version of PNG, just like GIF supports multiple-image animation	All of PNG's advantages; beats GIF compression ratios by factors of 10 to 100; much smaller file sizes compared to GIF due to sprites and loops	Limited support		Developing a subset of MNG - JNEG (JPEG Network Graphics) for single-image lossy compression
PNG (Portable Network Graphics) "ping"	Varies widely among browsers and programs	Designed to replace GIF, as well as TIFF to some extent	Greater compression than GIFs; alpha channels for variable transparency; gamma correction for system-independent color; 2D interlacing; lossless; patent-free	Not widely supported, though the W3C is behind it	24-bit, grayscale and 8-bit per pixel (where it works best)	PNG Specification 1.2, non-proprietary open-source
SVG (Scalable Vector Graphics)	It is described in XML; Adobe provides a plug-in for Netscape and MSIE, but there are many programs for viewing/editing; W3C supported	Web, wireless devices (with subsets of SVG called SVG Basic and SVG Tiny)	Very small file sizes with mathematical equations; gradients are possible, as are a number of other effects like drop shadows through filters	Few programs, but expected to grow		SVG 1.0 Specification, as recommended by the W3
TIFF (Tagged Image File Format)	Supported by many applications; cannot be embedded into a webpage	Most accepted type for printing	Lossless; colors can be stored in RGB or CMYK and IBM or Mac bit-order	Large files	1 to 64-bit integer signed or unsigned; 32 or 64-bit IEEE floating point	TIFF 6.

7.1.3 Audio

Format	Support	Uses	Advantages	Disadvantages	Bitrate	Standards
AAC (Advanced Audio Coding)	Decoder implementations are available from ARM, Cirrus Logic, Fraunhofer IIS, and Texas Instruments	High-quality audio much smaller than MP3; used for all digital broadcasting (SDTV, HDTV, digital radio) in Japan	Claims to be 30% more efficient at encoding than MP3, so a 128kbps AAC file would have the same perceivable quality as a 192kbps MP3; no royalties for content distribution	There is currently no commercial software codec, but the hardware is gaining momentum (Rio, the first maker of portable MP3 players, has bought a license); expensive Dolby licenses	Up to 48 channels with a maximum sample rate of 96kHz	ISO and IEC as part of the MPEG-2 specification
AC3	The standard in DVD audio	High-quality multi-channel audio	Converts 6 channel surround sound into 2, making really high bitrate mp3s; much smaller than aiff and wav; better than CD quality		Up to 448kbps	Dolby
MIDI (Musical Instrument Digital Interface) *.mid	All music composing software, most music editing software, and nearly all synthesizers, though support in computer audio programs is not as widespread	Designed for synthesizers and digital equipment to talk to each other, later developed for the computer	Very small size; if creating from a synthesizer or music composing software, the music will sound the same on all computers since it doesn't take into account different tracks and channels	Lacks specific sound control so though it will sound the same on all computers, after conversion it may not sound the same as what you originally wrote	8-bit serial transmission, 31.25kbps data rate	General Midi (GM) by MIDI Manufacturers Association; GS by Roland; XG by Yamaha
MP3 (MPEG-1 layer 3)	Playable in portable MP3 players, or in programs like Winamp, RealPlayer or Windows Media Player; recent	The most widespread form of audio on the Internet; usually downloaded directly,	Maintains high quality at low bitrates, compressing to 12:1 of waveform audio; streamable	Most audio CD players will not play MP3s burned onto a CD - a separate program is needed to decompress the files into WAV before burning	The bitrate is variable, but typically files are saved at 128kbps - about 1mb per 1min music	Developed under sponsorship by MPEG, formalized by ISO

	audio CD and DVD players	though it can be streamed				
RealAudio *.ra, *.ram	Playable through the free RealPlayer as well as other players and editors from RealNetworks that are available for purchase	Most widespread form of streaming audio	Streamable	Since it is compressed so much, the audio may sound like radio or telephone-quality	File is saved according to bandwidth preferences since it is usually streamed: 20kbps for dial-up modems, and as much as 220kbps for T1 lines	RealNetworks
Waveform *.wav	Now readable on Macs (Apple's AIFF format is equivalent to WAV as it is also uncompressed); most systems come with a basic music program that supports WAVs	This is the format audio must be in to be burned for an audio CD	When ripped from CD, it retains all audio data	Since it is uncompressed raw data, very large files result	44.1kHz, 16-bit, stereo	Microsoft
WMA (Windows Media Audio)	Windows Media Player; becoming increasingly widespread on the web	Streaming or downloaded	64kbps files sound just as good as 128kbps MP3 files and are half the size; streamable	Not all audio software and portable devices recognize this format, or will be allowed to due to proprietary restrictions	48kHz, stereo	Microsoft

7.1.4 Video

Format	Support	Uses	Advantages	Disadvantages	Bitrate	Standards
AVI (Audio Video Interleave)	Windows Media Player (now for Mac too) and RealPlayer; most widely used compressor is Cinepak, free with Video for Windows, though dozens of others are available	Most common format for audio/video data on the PC, as well as very common on the Internet	Data is arranged in chunks, lowering file size; every option is definable from display size and frames per second to bit depth for audio and video; some compressors can achieve up to 100:1 compression	Unless a good compressor is used, transmitting raw files over the Internet is impractical as files are very large	Typically 8 or 16-bit waveform sound in stereo or mono, sampled at 11, 22, or 44.1kHz; 24-bit color is usual	Microsoft; Open Digital Media (OpenDML) Consortium has defined extensions to support additional features for a more professional video production
DV and Mini-DV	Digital video cameras and non-linear video editing applications	Intraframe compression of digital video	High-quality, raw footage	A range of DV standards have emerged, all based on one format. But they continue to diverge, creating some incompatibilities. This can complicate interfacing and system integration.	On average, 25Mbits/s for video, up to 44.1kHz and 16bit for audio; the HDCAM format records video as high as 100Mbits/s	Each manufacturer has their own particular version of the format.
MPEG (Motion Picture Experts Group) *mp4, *.mg4, *mp2, among others <i>MPEG has produced multiple standards, each with different applications</i>	Numerous applications, including Windows Media Player and QuickTime	MPEG-4 could become the video standard for the web, like MP3 is for audio; MPEG-2 used for DVD codecs generally, and web, satellite and terrestrial broadcast; VCDs use MPEG-1	Maintains impressive quality over very constrained bandwidth; streamable; MPEG-4 compresses at a ratio of up to 10:1 of original DVD-quality size, with little loss; MPEG-4's object-based coding allows interactivity	Was not available for Mac users until recently; MPEG-4 charges licenses for de/encodes under the MPEG LA plan	Varies per standard	All developed by Motion Picture Experts Group; open format distributed by ISO; Joint Video Team still working on MPEG-4
QuickTime *.mov	Requires free download of QuickTime Movie Player to view; QuickTime Pro can be used for creating and editing	Multimedia tool offering the most creativity and flexibility; many believe it to be the best quality	Can layer up to 99 tracks of audio, video, 3D, text, Flash, HTML, VR; simply embedded into a webpage; superior compression; maintains good quality over constrained bandwidth	Inconsistencies in playback can occur because unlike AVI which bundles audio/video data per frame, QuickTime in larger .5 to 1 second blocks		Apple

RealMedia and RealVideo *.rm, *.rv	RealPlayer; RealNetworks provides a number of apps for editing, streaming, capturing, and creating	Streaming or direct-downloadable multimedia on the Internet	High compression rate, allowing for small files	Not always backwards compatible with older players; quality can be greatly reduced due to the compression, resulting in artifacts or motion that is not smooth	Handles up to 16bit sound, 24bit color	RealNetworks
Flash and Shockwave *.swf	Requires free download of Macromedia Flash or Shockwave Player to view, purchase of Macromedia Flash or Director to create, though free 30-day trial versions exist	Integrate interactive content into webpages, or use as movies like the other formats	To each other: Director's interface is simpler, Flash files are more streamlined. Flash content loads almost immediately, Shockwave gives you an ad. Director can be extended with Lingo for interactivity, and can embed Flash content. To other types: Vector graphics have smaller file sizes; plug-in distributed with every major browser so the majority of your audience should have it (77% and 69% respectively), many print resource guides are available; integrates with all other Macromedia products			Macromedia

7.2 Output device Specifications

In the MOBIlearn project three different categories of mobile devices are considered as target output device for the system:

- PDAs
- Mobile phones
- Tablet PCs

In the following sections the main technical characteristics of several models for each kind of device are provided. This should help in better understanding which are the constraints to be considered when creating Learning Objects.

7.2.1 PDAs

Model	Operating System	RAM Installed	Processor	Screen Resolution	Expansion Slot	Battery Life
HP iPaq H5550	Microsoft Windows Mobile 2003	128MB SDRAM	Intel 400MHz	240x320	1 SD Memory Card	6 hours, 5 minutes
Garmin iQue 3600	Palm OS 5.0	32MB	Motorola 150MHZ	320x480	1 SD Memory Card	3 hours, 45 minutes
Toshiba Pocket PC e335	Microsoft Pocket PC 2002	64MB SDRAM	Intel PXA250 300MHz	240x320	1 SD Memory Card	4 hours, 16 minutes
Toshiba Pocket PC e750	Microsoft Windows Mobile 2003	64MB SDRAM	Intel PXA255 400MHz	240x320	1 SD Memory Card, 1 CompactFlash card	3 hours, 55 minutes
Palm Tungsten E	Palm OS 5.2	32MB	126MHz Texas Instruments OMAP 311	320x320	1 SD Memory Card	3 hours, 30 minutes
Dell Axim X5	Microsoft Pocket PC 2002 Premium Edition	64MB SDRAM	Intel PXA250 400MHz	240x320	1 SD Memory Card, 1 CompactFlash card	6 hours, 22 minutes
Toshiba Pocket PC e350	Microsoft Windows Mobile 2003	64MB SDRAM	Intel PXA255 300 MHz	240x320	1 SD Memory Card	3 hours, 51 minutes
Sharp Zaurus SL-5600	Trolltech Qtopia	32MB SDRAM	Intel PXA250 400MHz	240x320	1 SD Memory Card, 1 CompactFlash card	4 hours, 10 minutes
Sony Clie PEG-TJ25	Palm OS 5.2	32MB	200MHz	320x320	Memory Stick	n/a
Palm m125	Palm OS 4.0.1	8MB	Motorola MC68VZ328 33MHz	n/a	none	n/a

The HP iPaq H5500 model characteristics are highlighted in yellow because this device (or a similar one) will be probably used in MOBIlearn during the user trials.

7.2.2 Mobile Phones

In this case, given the huge amount of models available on the market from several producers, only Nokia models are considered.

Model	Operating System	Internal Memory	Screen Size	Screen Colors	SMS/MMS	WAP	GPRS	Java Enabled	Stdby/talk Time
Nokia 9210i	Symbian OS	Up to 16 MB	640x200	4096	Yes/No	Yes, WWW browser in full color	No	Yes	4-10 h/up to 230 h
Nokia 7650	Symbian OS	Up to 3.6 MB	176x208	4096	Yes/Yes	Yes, WAP 1.2.1	Yes	Yes	Up to 4 h/up to 150 h
Nokia 6800	EGSM 900 /GSM 1800	Up to 4 MB	128x128	4096	Yes/Yes	Yes, WAP 1.2.1	Yes	Yes	up to 3-7 h/ up to 7-15 d
Nokia 6610	Nokia OS	Up to 625 kB	128x128	4096	Yes/Yes	Yes, WAP 1.2.1	Yes	Yes	up to 2-5 h/ up to 150-300 h
Nokia 6220	Nokia OS	Up to 4 MB	128x128	4096	Yes/Yes	WAP 2.0 with XHTML	Yes	Yes	up to 2-4 h/ up to 8 d
Nokia 3650	Symbian OS	Up to 3.4 MB	176 x 208	4096	Yes/Yes	Yes, XHTML over GSM data, HSCSD and GPRS	Yes	Yes	up to 2,5-4 h/ up to 150-200 h
Nokia 6600	Symbian OS	Up to 6 MB	176x208	65536	Yes/Yes	Yes, WAP 2.0 XHTML	Yes	Yes	up to 4 h/ up to 240 h
Nokia 9500	Symbian OS	Up to 80 MB	640 x 200 PDA display, 128 x 128 Cover display	65536	Yes/Yes	No separate WAP browser but support for WAP 1.3 content	Yes	Yes	Up to 4-6 h/ up to 200-300 hours

The Nokia 6600 model characteristics are highlighted in yellow because this device is the one indicated by Nokia as the most suitable to be used in MOBIlearn during the user trials.

The Nokia 9500 model (highlighted in green) is not available at present on the market (planned availability in the 4th quarter of 2004) but has been included in the table because it will support WLAN connections.

7.2.3 Tablet PCs

Model	Operating System	Processor	RAM	Hard Disk	Display	Battery Life
Fujitsu Stylistic ST 4120P	Windows XP Pro/Windows 2000 Pro	ULV Pentium 3 933 MHz	256-768 MB	30 GB or 60 GB Ultra DMA	10.4" XGA TFT (1024x768)	4 hours
HP TC1000	Windows XP Tablet PC Edition	Transmeta Crusoe 1 GHz	256-768 MB	30 GB or 40 GB	10.4" XGA TFT (1024x768)	-
Xplore iX104	Windows XP Tablet PC Edition/Windows 2000 Pro	ULV Pentium 3 866 MHz	256-512 MB	20 GB or 40 GB	10.4" XGA TFT (1024x768)	-
ACER TravelMate C110	Windows XP Tablet PC Edition	ULV Pentium 3 900 MHz.	128-256MB	20GB or 30GB	10.4" XGA TFT (1024x768)	3,5 hours
Toshiba Portege 3500	Windows XP Tablet PC Edition	ULV Pentium 3 1.5 GHz	256MB-2GB	40GB, 60GB or 80GB	12.1" SXGA TFT (16M colors at 1400 x 1050)	4,3 hours

7.3 Interoperability Specifications

While reusability offers great promise for the development of online learning material, technical interoperability remains an important concern. A learning object may be built for a specific computer platform or course management system. To reuse this learning object in another LCMS, this LCMS must understand the purpose of the learning object and be able to render the learning resource just as the first LCMS. Successful reuse also requires learning objects to be discovered and managed in a consistent way across different platforms.

The discovery, management, and exchange of learning objects can be considerably simplified by providing standardized information on each learning object. This information is called metadata and facilitates the search, evaluation, acquisition, and use of learning objects by learners, instructors, or automated systems. However, metadata by itself is useless in promoting reusability among organizations. To be

effective, metadata needs to be standardized internationally and adapted locally. Recognizing this, there have been a number of efforts worldwide to develop standards for learning object interoperability.

The IEEE 1484.12.1-2002 Standard for Learning Object Metadata (LOM) (ltsc.ieee.org) is the first accredited standard for learning technology. It is essentially a cataloguing scheme for learning objects, storing data on each learning object. The data elements that describe a learning object are grouped into nine categories. The Instructional Management System (IMS) Global Learning Consortium (www.imsglobal.org) is the most advanced group developing learning technology interoperability specifications. The specifications listed in the following table are those that have a direct bearing on learning objects.

IMS Specification	Purpose
Learning Resource Metadata	Same purpose as IEEE LOM and contains identical elements
Content Packaging	Allows learning objects to be packaged into interoperable content packages
Simple Sequencing	Allows sequencing of learning objects within a content package
Question and Test Interoperability (QTI)	Allows the interoperability of test and assessment data between LCMSs, content authors and others

In addition to standards and specifications, reference models play an important role in the development of systems since they show how different parts of a system interact with each other and hence provide guidelines for the definition of these parts. Reference models have a significant influence on standardization efforts, and in turn can be used to build actual systems that conform to a standard (which are then said to be compliant with the model). An important reference model is the Shareable Content Object Reference Model (SCORM) (www.adlnet.org/Scorm), which addresses fundamental issues such as finding, launching, and managing content. SCORM consists of three main sections: an Extensible Markup Language (XML)-based specification for representing course structures (so courses can be moved from one server/LMS to another); a set of specifications relating to the run-time environment, including an API, content-to-LMS data model, and a content launch specification; and a specification for creating meta-data records for courses, content, and raw media elements. The Shareable Content Object Reference Model is a set of interrelated technical specifications built upon the work of the AICC, IMS and IEEE to create one unified 'content model'. These specifications enable the reuse of Web-based learning content across multiple environments and products.

7.3.1 Markup Languages for Learning Object Content

Learning objects today are mostly Web pages containing text, images, audio and video. These Web pages are designed in HTML using some Web page authoring tool. However, XML is currently seen as the markup language of the future, allowing content to be specified in a form that is independent of its presentation. By separating content from presentation, it is possible to present the same content in many different ways to different learners, in different courses, and in different learning systems. Thus, a level of flexibility is achieved that is far superior to what can now be done with HTML.

However, flexibility has its price. XML requires special tags to markup different sections of the content. Now, assume that special tags have been defined to create a set of learning objects. In order for these learning objects to be reused in another learning system, that learning system must understand the meaning of the tags to correctly render the learning object. The IMS has made some headway in this with

assessment items in the QTI Specification. However, there is no standardized format for marking up the content in individual learning objects using XML, severely restricting the reusability of these learning objects. The problem does not end with a set of commonly understood content tags. Content for different domains will need different markup tags. For example, Computer Science content will contain markup tags such as “algorithm”, “code example”, etc., which has no counterpart in an English language course. Thus, there is a need to create markup languages to define content for learning objects in different domains.

7.3.2 Learning Object Repositories

In order to reuse learning objects on the Web, they must be made available somehow to potential users, and there must be mechanisms to allow users to discover, obtain rights to, and use these learning objects over the Web. A number of repository-based approaches are currently being used to encourage the discovery, exchange, and reuse of learning objects. These include using global repositories based on a client/server approach, employing brokerage services, and providing peer-to-peer access to local repositories of learning objects. Global repositories usually maintain links to learning resources stored elsewhere on the Web. An increasing number of global repositories for learning objects are appearing. One common feature of these repositories is that they do not physically store the learning objects. They are essentially global catalogues for learning objects that are available at different levels of granularity.

To make it easier to find and reuse learning resources stored in global repositories, the IMS is presently working on a Digital Repositories Interoperability (DRI) Specification. The current draft specification recognizes two different repository types, one reflecting established practice for repository interoperability and the other implementing the XQuery and SOAP-based recommendations put forward in the specification. The W3C XQuery language uses the structure of XML to intelligently express queries across all kinds of XML data sources. SOAP is the Simple Object Access Protocol and is currently a W3C Technical Report. It provides a simple and lightweight mechanism for exchanging structured and typed information between peers in a decentralized, distributed environment using XML.

To understand how a DRI-compliant repository works, consider an XML client application that is part of an LCMS. This client wishes to query a repository to determine if it has certain learning objects. The XML client formulates a query in XQuery based on the IMS Metadata Specification. This query is then packaged as a SOAP message and sent to the repository. The repository uses an XQuery engine to execute the query against its metadata in its database. The results of the query (IMS metadata for each learning object that satisfies the query) are expressed as XML and sent back to the XML client using SOAP. Finally, the XML client examines the metadata and obtains more information about the learning object such as its location and copyright restrictions.

Another way to make learning objects publicly available is by using a brokerage service. The Universal Brokerage Platform (UBP) (www.ist-universal.org) provides a full range of services to support the exchange of learning objects between producers and consumers. UBP catalogues learning objects using metadata derived from the LOM and IMS metadata specifications. Consumers enter search parameters for the learning objects they are looking for, and UBP informs consumers when these learning objects become available. A booking process is used as a means of protecting intellectual property rights. It requires consumers to agree on the offer terms associated with a learning object before it can be accessed. Thus, brokerage

services provide a practical solution to the problems of payment and copyright in a global environment of learning objects.

7.4 Accessibility Specifications

Every person learns differently. At its best, online education allows each user to interact with learning material in his or her preferred way, relying on their individual strengths while discounting as much as possible their weaknesses. The principles of excellent software design call on developers to work in full knowledge of the range of human skills and limitations. Software designers of teaching materials and activities, in particular, must strive to achieve this high standard.

When a user has a disability, access to learning software may depend entirely on how flexibly that product can deliver its content. Some users may need only to modify the parameters in which media is presented; other users may require entirely different media. Developers who achieve the kind of flexibility that diversity requires will enhance the accessibility of their product.

At a minimum, developers should provide text representations for all media types. This baseline will help address access for many users. That said, it should be noted that users with learning disabilities benefit from graphical presentations. For this reason, the practice of providing text-only content as an alternative to inaccessible multimedia content may not be an effective solution for users with cognitive disabilities.

A number of resources that address flexible media delivery are currently available. The W3C's Web Accessibility Initiative provides accessibility guidelines for W3C technologies such as HTML, XML, SMIL, CSS & SVG. It also provides more general guidelines for web content accessibility, authoring tool accessibility, and user agent accessibility.

Some guidelines for the accessible delivery of text, audio, images, and multimedia are provided in the following sections. (Barstow, McKell, Rothberg, & Schmidt 2002)

7.5 Text

When text is correctly structured and formatted, it can be the most flexible way to present content. To make distributed online learning accessible, developers of learning platforms must provide a means to render digital text in alternative formats. Specifically, it should be possible to render text as:

- **Visual information.** Text can be displayed on computer screens or other electronic devices (e.g. personal digital assistants, cell phones, e-book readers).
- **Audio information.** Text can be translated into speech using recordings or via synthesized speech provided by a computer.
- **Tactile information.** Text can be displayed on refreshable Braille displays or printed using a Braille embosser.

Common text accessibility problems include:

- hard-coded fonts that prevent users from changing style, size, color.
- text presented with background images or poor contrast colors that hinder readability.
- text presented in an image format that screen readers and Braille displays cannot transform.

- multi-column formats (including some tables) that screen readers cannot process in the correct order.

Learning system developers may enhance the accessibility of text for all users by following these practices:

- Offer features that allow the user to customize fonts and backgrounds.
- Allow ATs to have access to the source code.
- Use validated XHTML.

Content creators or educators may enhance the accessibility of text for all users by following these practices:

- Choose text formats that offer the most accessibility (e.g. XHTML, plain text).
- Use true text, and not graphical representations of text.
- Structure the text appropriately, identifying headings and other structural elements.
- Use styles or stylesheets to provide a flexible display.

7.6 Images

Images can provide essential information. But without text support, images are not accessible for users who are blind or have low-vision. Developers must provide users with a way to access visual information. Providing text identification, or alternative text, will also benefit users of text-only browsers, such as mobile phones. In addition to providing, developers should ensure that images are scalable, so that users can enlarge them for better clarity.

Common image accessibility problems include:

- Failure to provide alternate text.
- Poor image resolution that restricts the ability of low-vision users to enlarge images.

Learning system developers may image enhance the accessibility of images for all users by following these practices:

- Provide a means to include text alternatives of images.
- Provide a zoom feature.

Content creators or educators may enhance the accessibility of images for all users by following these practices:

- Provide text alternatives for images.
- Use SVG features that improve accessibility.
- Use the highest practical resolution for bit-mapped graphics when use of SVG is not possible (e.g., photographs).

7.7 Audio

Audio elements can add to the general appeal of online learning materials while making them more accessible to those who are print-impaired learners, such as those with visual impairments or dyslexia. However, developers should provide alternatives to ensure that learners who are deaf or hard-of-hearing are not disadvantaged.

Common audio accessibility problems include:

- lack of captions and/or transcripts.
- poor sound quality.
- inability to control volume.

Learning system developers may enhance the accessibility of audio for all users by following these practices:

- Provide a means to include captions and/or transcripts.
- Provide volume controls.
- Provide visual equivalents to audio alerts (e.g. show a text alert on the screen whenever an error beep is played).

Content creators or educators may enhance the accessibility of audio for all users by following these practices:

- Provide transcripts or captions for all essential audio.
- Consider providing other forms such as ASL or captions with images.

7.8 Multimedia

Multimedia is the combination of text, graphics, video, animation, and sound. Thus, a given piece of multimedia content combines the access needs of each media type represented. Multimedia can be useful for many groups of learners, since a multi-modal presentation of information can be easier to understand. In general, users benefit when alternatives are available for each media type.

Common multimedia accessibility problems include:

- digital videos without captions, transcripts or audio descriptions.

Learning system developers may enhance the accessibility of multimedia for all users by following these practices:

- Provide the means to include accessibility features, such as captions, transcripts, and audio descriptions, within the multimedia format provided by the application.

Content creators or educators may enhance the accessibility of multimedia for all users by following these practices:

- Follow all relevant suggestions for enhancing accessibility for text, audio and images, since multimedia can combine all of these elements.
- Provide audio description describing essential visual elements for video content.
- Consider the importance of the timing of media delivery when planning access features. For example, a "talking head" video may need only a stand-alone transcript of the audio, but a documentary including graphics and other important visuals may require captions in order to maintain the link between visuals and narration.

8. Learning objects (LOs) vs. mobile learning objects (m-LOs)

While much attention has been paid to delivering learning objects through existing systems, and similarly to the use of mobile devices in learning, connecting the two has taken a back seat. However, there is considerable potential in supporting learning “on the go” through small and system-supported content. As we recognize the transition from formal courses to informal learning, from learning Just In Case to Just In Time, we are similarly recognizing the potential to move to granular learning experiences—a blend between e-Learning, knowledge management, and performance support.

There are several levels at which this can be developed:

- At a base level, you just have a library of material that learners can choose from.
- At a more advanced level, you use demographic and behavioral data to categorize courses and optimize the offerings.
- Ultimately, you track individual users and base decisions upon a precise picture of their experience, knowledge, individual differences, and, consequently, needs.

In a pervasive learning environment, people can take their mobile devices anywhere, using them in various environments to access information and perform different tasks without the constraints of time and location. At the same time, mobile devices may have some knowledge about the environment and user preferences, which could enable them to provide better services to users.

As users are beginning to rely more heavily on mobile devices, there is a growing need for applications to bring information to the devices. However, as for the Internet and other applications that make use of various types of multimedia data, such as a digital library, most multimedia content was designed and organized with desktop computers and high-speed networks in mind. They usually contain rich media data, like those described previously, which are not suitable for mobile devices with limited display capability, process power and network bandwidth. Therefore, in order to provide services to mobile users, the quality of media presentation often needs to be adjusted according to the network bandwidth and the capabilities of their devices. Furthermore, the growing plenitude of multimedia information also calls for personalization of the multimedia presentation according to the user's individual preference. As a result, the elimination of the mismatch between rich multimedia content and the limited device capabilities becomes a challenging task.

8.1 Media authoring and processing: techniques for adaptation

In order to increase accessibility of multimedia information, many media processing techniques can be used to enable media adaptation. Several existing systems apply image processing techniques to adapt the embedded images of a web page according to client display. Some other techniques, such as text summarization, video-to-image transformation, are applied in some multimedia applications. Based on different standards and perspectives, we can classify these techniques as follows (Lei, Z. & Georganas, 2001).

According to the adaptation target context, media adaptation techniques can be divided into the following two categories:

- *Media adaptation to technical infrastructure*: Technical infrastructure includes device capabilities and network connections. Current pervasive

devices vary widely in their features such as screen size, resolution, color depth, computing power, storage and software. They also use a variety of network connections range from cable to wireless, with different effective bandwidth and network latency. Media adaptation technology should be able to provide an appropriate presentation to different devices. For example, in order to display images on devices with a small screen and limited display capability, reducing the size or resolution for each image will help to fit the image on the small screens of devices.

- *Media adaptation to user preferences:* For a specific multimedia presentation, individual users may have different requirements on the level of details or some other parameters. For example, given a medical tele-learning system, both a professor and a student are interested in a surgery, but the professor wants to get the in-depth multimedia material for his lecture, while the student only needs an abstraction of the same material to pass the upcoming exam.
- According to when the different media alternatives are created, media adaptation techniques can be divided into the following two categories:
 - *Static adaptation:* At authoring time, multimedia formation is preprocessed and stored in multiple versions that differ in quality and processing requirements. At presentation time, the appropriate version will be selected at runtime depending on the user's context. In order to eliminate extra processing overhead at presentation time, most current web sites create multiple versions of information at authoring time.
 - *Dynamic adaptation:* Multimedia information is processed and delivered on the fly. The available alternatives are determined for the specific context at presentation time. For example, when network bandwidth is not enough, we can drop less important data and give a summarization of the multimedia presentation. As we have mentioned before, the diversity of devices and network connections will make it difficult and expensive to create multimedia content separately for each individual type of device at authoring time. Moreover, the nature of network connections is not always known at authoring time. Therefore, technologies that can dynamically adapt multimedia information to diverse client devices and network connections will become critical.
- According to the media types involved in adaptation, media adaptation technologies can be divided into the following two categories:
 - *Single media element adaptation:* A lot of current best-effort adaptation techniques are considered with switching between different qualities or formats of single media elements. For example, most images can be significantly compressed without an appreciable decrease in quality. GIF-to-JPEG or color-to-grayscale transformations could be able to simply reduce the physical size of an image.
 - *Cross-media adaptation:* Single media element adaptation is limited to an inherent lower bound, i.e., the lowest acceptable technical quality of the respective media type. Cross-media adaptation is the process of transforming the content from one media type to another so that the content can be processed by a particular device. For instance, most handheld computers are not capable of handling video data due to their

hardware and software constraints. Transforming video into sets of images and extracting audio or caption will enable the devices to access the information contained in the video. In this case, users will be able to receive useful information in whatever form their devices can handle.

- According to the abstract presentation level, adaptation can be divided into the following two categories:
 - *Semantic Adaptation*: In principle, semantic adaptation is a selective process. Based on available and requested information, multiple pieces of information are combined into a complete presentation. Semantic adaptation is affected by the semantic structure of a presentation, which determines the relative data in the final presentation. For example, most current ecommerce web sites usually contain many images of banners, logos, and advertisements. These data often consume a good deal of network bandwidth, and are redundant or not of interest to a user. If we can define the semantic structure of the web page at authoring time, and then generate a new version of web page by removing redundant objects, the efficiency of information delivery will be improved.
 - *Physical adaptation*: Physical adaptation of media is defined as the combination of conversion, scaling and distillation processes guided by the characteristic of media format and physical QoS.

The above classification would help us understand the adaptation techniques and use appropriate techniques for different application scenarios.

8.1.1 Architectural issues

One important design issue is to decide where the adaptation resides. Adaptation operations can take place in the server, the proxy, the client or combinations. Each design choice has its advantages and drawbacks. The main issues to consider include how deployable the system is, how efficient the utilization of bandwidth, CPU, and memory is, as well as how effective the adaptation is.

8.1.1.1 Server-based adaptation

In server-based adaptation, the media server is responsible for analyzing the context profile and discovering how much bandwidth is available. It then selects the appropriate adaptation strategy. Using the server-based adaptation has the advantage that it allows both static and dynamic adaptation. The adaptation may have the best effect since the content authors can preview the adapted result under different viewer preference and conditions.

Placing the adaptation on the server also has drawbacks. It complicates the implementation of an origin server and the algorithms for generating appropriate presentation to a request, which results in additional computational load and resource consumption on the server. The static approach generates multiple versions of the content, thus requires more storage space.

8.1.1.2 Proxy-based adaptation

In a proxy-based adaptation, the client connects through a proxy, which decides and performs the adaptation on the server response, and then sends the transformed content back to the client. Adapting on the proxy means that there is no need to change existing clients and servers. The proxy can transform existing multimedia content so that existing content does not have to be re-authored. Adapting on the proxy also reduces the computation load of the origin server.

In proxy architectures, there is less author control on the outcome of the adaptation, and it is difficult to determine what alternation “looks good” for any general content.

8.1.1.3 Client-based adaptation

Client-based adaptation mainly depends on the capability of the devices. With client-based adaptation, selection of the best representation is performed by the device after receiving an initial response from the origin server. Selection is based on a list of the available representations of the response included within the response. Client-based adaptation is advantageous when the origin server is unable to determine device capabilities from examining the request, and when public caches are used to distribute server load and reduce network usage. Client-based adaptation suffers from the disadvantage of needing a second request to obtain the best alternate representation. This second request is only efficient when caching is used. Moreover, the adaptation is not transparent to the user.

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10. Glossary

Accessibility: A characteristic of technology that enables people with disabilities, or other special needs, to use it. For example, can a web site be navigated by people with visual, hearing, motor, or cognitive impairments?

API: An Application Program Interface (API) is a language and message format built into an application that allows it to communicate with operating systems or programs such as database management programs. APIs provide a way for eLearning computer applications to speak to other administration systems such as student information.

Asynchronous: Asynchronous eLearning happens when communication between people does not occur simultaneously. For examples exchanging e-mail messages with a mentor, and posting messages to a discussion group.

Authoring Tool: A software application used by teachers and instructional designers to create eLearning courseware. Types of authoring tools include instructionally focused authoring tools, Web authoring and programming tools, template-focused authoring tools, knowledge capture systems, and text and media creation tools.

Blended learning: Learning events that combine aspects of online and face-to-face instruction. Also called hybrid learning.

Chat: Real-time text-based communication using computers. Chat can be used in eLearning for student questions, instructor feedback, or even group discussion.

Collaborative Tools: allow learners to work with others via e-mail, threaded discussions, chat, shared file space, shared whiteboard and other tools.

Content Management System: (CMS) is used to store and subsequently find and retrieve large amounts of data. Content Management Systems work by indexing text, audio clips, images, etc., within a database. Using search capabilities, users can quickly find a piece of content from within a database by typing in keywords, the date the element was created, the name of the author, or other search criteria.

Discussion Forums: discussion forums allow people to communicate by posting messages and replies to messages under the heading of a particular topic. A collection of messages and replies about a topic is often referred to as a thread.

eLearning (electronic learning): Term covering a wide set of applications and processes, such as Web-based learning, computer-based learning, virtual classrooms, and digital collaboration. It usually means the delivery of content using the Internet.

Granularity: The degree of detail something can be broken down into, or the number of discrete components making up any type of system. In eLearning, granularity is defined by the number and size of content chunks.

IMS: The Instructional Management Systems (IMS) is a set of technical specifications defining how learning materials will be exchanged over the Internet and how organizations and individual learners will use these materials. The goal of these specifications is the adoption of a set of open standards for Internet-based education.

Instant messenger (IM): Software that detects and lists users' selected "online buddies" (friends, family, co-workers, and so forth) and enables users to send short text messages back and forth to them. Some instant messenger programs also include voice chat, file transfer, and other applications.

Intellectual property: An idea, invention, formula, literary work, presentation, or other knowledge asset owned by an organization or individual. Intellectual property can be protected by patents, trademarks, service marks, and/or copyrights.

Knowledge Management System: A Knowledge Management System is an application that collects, stores, and makes information available among individuals in an organization. This system's primary purpose is to capture an organization's collective knowledge and then make it simple to retrieve and re-use.

LCMS (learning content management system): A learning content management system is an environment where developers can create, store, reuse, manage and deliver learning content from a central database. LCMS generally work with content that is based on a learning object model. Learning Content Management Systems typically strive to achieve a separation of content, which is often tagged in XML, from presentation. This allows many LCMS to publish to a wide range of formats and platforms.

Learning Management System (LMS) or Course Management System (CMS): A Learning Management System (LMS) is software environment that automates the administration of eLearning and provides tools for content development and delivery. All Learning Management Systems manage the log-in of registers users, manage course catalogues, record data from learners, and provide reports to management. Usually an LMS will contain a discussion forum, chat, quiz making, and gradebook tools and a way to present both text and media content.

Learning Object: Learning Objects refer to self-contained chunks of instructional content that can be assembled with other Learning Objects to create courses and curricula, much the same way a child's Lego blocks are assembled to create all types of structures. Learning objects are often stored in databases with the view that they will be used many times and in different contexts.

Media: Text, graphics, audio, video, or other element used to teach.

Open source software: Generally, software for which the original program instructions, the source code, is made available free so that users can access, modify, and redistribute it. The Linux operating system is an example of open source software.

SCORM (Sharable Content Object Reference Model): A set of specifications that, when applied to course content, produces small, reusable learning objects. SCORM-compliant courseware elements can be easily merged with other compliant elements to produce a highly modular database of training materials.

Streaming media (streaming audio or video): Audio or video files played as they are being downloaded over the Internet instead of users having to wait for the entire file to download first. Requires a media player program such as Quicktime, Windows Media player or Real Player.

Synchronous: Synchronous, or live eLearning, means that communication occurs at the same time between individuals and information is accessed instantly. Examples of synchronous eLearning include real-time chat, and video/audio conferencing.

XML (Extensible Markup Language): The next-generation Webpage coding language that allows site designers to program their own markup commands, which can then be used as if they were standard HTML commands. This is used to prepare learning objects for database usage.