BeLearning: Accessibility in Virtual Knowledge Spaces for Mathematics and Natural Sciences

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This paper is based on the program and the experiences of the newly started project "BeLearning – Accessibility in eLearning for mathematics and natural sciences" [6] at Berlin University of Technology, funded by the European Social Fund (ESF) Germany.

The development of "barrier-free" eLearning and eResearch environments is still a barely investigated field due to the lack of concepts to support accessibility of interactive components and to transform between different media types. On the other hand flexibility and adaptivity as the outstanding characteristics of new media and new technologies allow new methods to support persons with special needs and handicaps. In this paper we discuss some approaches which at least have the ability to contribute to overcome these problems focusing on eLTR-environments (eLTR := eLearning, eTeaching, eResearch) for mathematics and natural sciences.

Keywords: Accessibility; Virtual Knowledge Spaces; Mathematics; Natural Sciences; Semantical Encoding; Visualisation; Interactivity

1. Background

Despite equal opportunity legislation and other laudable initiatives, handicapped persons are highly disadvantaged in their chances for education and professional training. These circumstances often lead to massive restrictions for their occupational choice and their possible fields of work.
A number of guidelines (through W3C [19], EC, national governments and others) have been passed during the last years to address this issue. The majority of these guidelines focus on easy access to (more or less static, less interactive) information portals. So far these standards do not state sufficient recommendations for knowledge, learning or expert portals. They are not particularly applicable to this area as they barely integrate the characteristics of the new media as for example multimediality and interactivity. These, however, are the properties, which lead to new presentation approaches, to new forms of teaching and learning and which are essential in the development of new learning environments. The existing guidelines do neither address the implementation of highly multimedia-based interactive learning and teaching contents for handicapped people, nor are they well-suited to this task.
Another shortcoming of current eLearning practice is the lack of handicapped accessible approaches from the pedagogical point of view. Global guidelines are not able to provide recommendations for effective eLearning concepts, particularly in field-specific applications.
At the same time new media offer a great potential for the teaching of physically challenged people. First, the possibilities for distributing teaching materials and communicating between handicapped and non-handicapped people have been dramatically improved by computers and the world wide web. Secondly, the appropriate use of new media technology allows the complete separation of content and representation enabling the presentation of the same content piece through different media types adapted to particular persons with different sensory perceptions. Finally, in comparison to traditional teaching materials and media forms the modern information and communication technologies possess new approaches concerning far-ranging user adaptivity concepts through flexible content adaptation to individual needs on all levels. The flexibility of the separation of content and representation presupposes however an extensive semantical encoding of the complete content: supporting the underlying semantic technologies is vital in the realisation of a broad accessibility of highly interactive virtual knowledge spaces and incorporating intelligent tools for the development and administration of content. Here, it is important to mention that semantical encoding may not be restricted to the content elements themselves, but has to be extended to all aspects which are highly content-related as for example navigation mechanisms.

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For the conceptual design of modern eLTR-environments two major problems concerning "accessibility" are of primary importance:

- *Visualisation*: Existing standards e.g. by the W3C [19] focus on transforming pictures into text. Thereby it is often overlooked that the media type "picture" is playing a major role during the learning process of complex contents. Sophisticated, abstract interrelations and concepts are often taught easier by a single illustration than by texts filling pages. The abdication of visualisations implies a massive reduction of contextual, field-specific, and pedagogical quality of the teaching material. Thus, authoring tools not only have to support the transformation of illustrations but also alternative representation forms that still have to be developed.

- *Interactivity and non-linear navigation*: The role of interactive scenarios is comparable to the relevance of visualisations: Here, text transformation as currently recommended by the guidelines is an extremely insufficient substitute. Interactivity is substantially required to realise self-oriented, active, and explorative learning in eLearning environments. Interactivity is also the basis to implement cooperative learning scenarios. Authoring tools have to cover a barrier-free realisation of simulation scenarios and the control of interactivity as well.

The resulting challenge is a matter of multidisciplinary research, involving the fields of mathematics, pedagogics, psychology, new media technology and computer science, in particular questions of standardisation and semantical encoding. Some technological aspects will be discussed in the following with focus on visualisations and interactivity.

2. Approaches & Concepts

Current recommendations and guidelines (e.g., [3], [19]) mostly address the following main questions:

- *Presentation*: e.g., accordant content (text) for audio and video elements as well as visual signs for acoustical signals, presentation is coherent without colour, presentation supports assistive technologies, time flow controlled by users, support comprehension with pictures, etc.

- *Navigation & Functionality*: e.g., functionality is independent from I/O-device, allocation of information about objects, context and orientation, transparent navigation, shortcuts for deep linking, etc.

Thereby demands of different user groups may lead to incompatible claims: e.g., blind people may have the wish to get as much linear arranged text as possible whereas deaf people (who's understanding of the literary language is often reduced due to the fact that it is not their mother tongue) prefer visualisations and multidimensional representations of the dependencies between different content particles. Therefore, the solution cannot be found in a "one serves it all" model. Rather, we have to face the diversity of different approaches and support new models of far-ranging user adaption. Environments are needed that allow users to tailor system input and output modalities to their capabilities and preferences. In the following some approaches for eLTR-platforms in mathematics are discussed. Since the audio media type is not very prominent in teaching mathematics, the discussion is aimed at texts and visualisations by images and applets, also including some ideas to the question of interactivity of the latter ones.

2.1 Media type: text

The general concept to produce accessible content comprises at first the idea of semantical encoding of all relevant information. Presently, there are two important approaches for the semantical encoding of text-based mathematical content:
MathML Mathematical Markup Language [18] can be used to encode both the presentation of mathematical notation for high-quality visual display ("MathML Presentation Markup"), and mathematical content, for applications where the semantics play more of a key role such as scientific software or voice synthesis ("MathML Content Markup").

OpenMath [14] is designed as an – again XML-based – semantical meta language of mathematics focusing on the communication between different system and software components. The semantics of mathematical objects is given by content dictionaries. So-called “phrase books” act as an interface between different software applications and the OpenMath language.
MathML and OpenMath form the basis of the OMDoc-format (Open Mathematical Document) which serves as a content markup scheme for mathematical documents including articles, textbooks, interactive books, and courses. OMDoc also acts as a content language for agent communication targeting the interconnection of mathematical software. OMDoc approaches this goal by attaching information to mathematical documents that identifies the document structure, the meaning of text fragments, and their relation to other mathematical knowledge.
Markup technology is not the only means of enhancing accessibility of text-based contents; interface design of assistive technologies and devices also play an important role:

- *Setting mathematical formulas*: Mathematics presents a special challenge to the goal of barrier-free eLearning environments since its language contains a large number of extra symbols. LaTeX represents the worldwide standard for the mathematical community, and within the German-speaking countries LaTeX is also the basis for coding mathematical symbols in Braille. The coding uses ASCII-symbols for regular text, to express mathematical symbols commands come into place. Being a “semi-semantic” language so far, LaTeX dialects currently evolve to support a stricter enhanced description of mathematical content (sTex). On the other side, for the blind people’s “daily use” there are ambitions to reduce variations and ease the usage of the LaTeX language.
- *Non-linear content arrays*: WWW pages and eLearning environments make heavy use of non-linear content alignment (not for layout reasons but) to communicate information – non-linear navigation networks, tables and annotated diagrams may serve as examples. So far, two-dimensional arrangements of text create big problems for assistive technology devices; e.g., most braille devices cannot display more the one row at the same time which leads to the necessity of some kind of “linearisation”. The present approaches are characterised by the claim to flatten the content “somehow”, thereby losing parts of the original information. The future challenge is to develop “linearisation models” which still carry the complete information of the multidimensional structure.

2.2 Media type: image

A picture tells more then thousand words and especially illustrations, graphics, diagrams, and graphs of coordinate systems are important in mathematics.
To adapt images to different user groups (and in particular, to transform images into different media types) semantical coding of graphics is an important task. Whereas today semantical coding of all types of pictures as a whole is a rather unpromising task, the restriction to mathematical content-related pictures has to be estimated differently. Since the origin of mathematical visualisations usually is of an artificial nature the specific characteristics of computer-generated pictures can be utilised. Also, mathematical pictures are based on a limited amount of typical elements as e.g. graphs, curves, coordinate axes, etc. which significantly reduces the complexity of this task.
A new approach followed within the BeLearning project is the usage of applet-related technologies to solve the problem of semantic encoding of pictures: Within the Mathlet Factory project [13] (subproject of the Mumie-project) a java framework has been developed serving as an authoring tool for mathematics-related applets. Content and layout are clearly separated since by design of the software first the mathematical objects are declared with their attributes and dependencies and then customisably rendered in a second step. Applying this concept to graphics, at first a mathematical model has to be designed, describing the illustration in a semantical way. In a second step a rendering creates - individually adapted to the user - the illustration (or some other forms of presentation). An additional advantage of this concept is the unification of the media types “image” and “applet”.
One of the major obstacles in the creation of semantically-enriched multimedia content such as images or applets is found in the lack of widely-accepted standards of meta-data supporting semantic structuring. The W3C has been introducing a basic framework, RDF (Resource Description Framework), for encoding meta-data based on XML which does not specify a format for semantic meta-data, however. At

the moment, all efforts concerning meta-data describing multimedia content are concentrated on audio, video or still image sources, mostly ignoring more interactive content like applets. Current international standards for still image or video content, such as MPEG 7, are often restricted to purely technical information while semantic-based standards such as TEI (Text Encoding Initiative) headers, ICPSR (Inter-University Consortium for Political and Social Research), EAD (Encoded Archival Description) or CIMI (Consortium for the Computer Interchange of Museum Information) have not yet found wide acceptance and are in competition with proprietary standards developed by individual subject communities and market sectors. The creation of semantically structured meta-data to be associated with visual content is currently limited to the addition of information by hand, either by the author himself or by the person building an image database. This tedious process is supported by rather simple automated tools extracting simple semantic information from low-level, visual features accessible through purely stochastic measures (colour, simple shapes).

2.3 Media type: applet

The most difficult task in providing accessibility to people with disabilities concerns the interactivity of multimedia objects. Here, java applets are extremely important as they present the most widespread technology for the realisation of ambitious interactive content components. Within the Mumie project, applets developed within the Mathlet Factory subproject [13] are used to enable complex training environments and experimental scenarios.
To enable applet accessibility, screen readers play the most important role among the existing assistive software tools: screen readers translate the contents of the screen into braille, voice output, or audible cues. For this purpose, screen readers control the information about the objects of the desktop in a so-called off-screen-model. Additionally, they use different system information about processes and objects. Hereby, they rely on the support of the Java Accessibility API of Sun (part of the Java Foundation Classes JFC, for details see [4]): Various user interface application programs (APIs) specify standard methods for applications to interact with each other and the system. Assistive software such as screen readers monitors the state and behaviour of applications partly by tracking their use of API functions. For this reason, applications that do not use standard APIs create serious usability problems for people with disabilities.
Presently only a very few screen readers are capable to handle applets to a certain extent: here, “JWAS” is the most common one. However, it is important to mention that currently even the most sophisticated assistive technologies are only capable to communicate the content/elements of an applet – they are unable to describe the relations between the different elements, and they are unable to support the interaction of the human user with the computer system.
A different approach is undertaken by Microsoft: Within the Microsoft Active Accessibility MSAA ([11]), the IAccessible-interface has been developed (first implementation in Windows 98). Screen readers using this interface have in principle the ability to obtain the necessary information about objects, relations and implemented interfaces. Currently, MSAA is supported in particular by the Internet Explorer and Mozilla. Nevertheless, since Microsoft’s accessibility strategy is changing to a new API in Longhorn, the further development of MSAA can not be assured at this time.

3. BeLearning – The Project

The BeLearning-project (“BeLearning – Accessibility in eLearning for mathematics and natural sciences”, [6], Berlin University of Technology, funded by the European Social Fund ESF) aims to enable handicapped people to profit equally from modern information technologies. Utilising the flexibility and the adaptivity of the new media, the target is to expand the accessibility of modern interactive education material for people with special needs. The central goal of the projects’ efforts is the development of “barrier-free” highly-interactive eLearning and eResearch environments focusing on the area of mathematics, natural sciences and engineering in university education. Within the BeLearning project, the following steps will be taken:

1) The guidelines and standards for the design of web-based information material developed by the World Wide Web Consortium W3C will be extended and adapted to the requirements resulting out of multimedia-based learning and teaching scenarios.

2) Existing platforms (in particular the Mumie-platform [12], [2] and the virtual laboratory VideoEasel [16], [8], both highly interactive eLearning environments for mathematics and natural sciences) will be extended to support these additional specifications.

3) Authoring tools will be developed which support the creation of “barrier-free” learning and teaching material (of different media types, based on the existing technologies) for scientific education at schools and universities.

4) Advanced training material will be composed for teachers and software designers to qualify them for designing and developing eLTR-scenarios and eLTR-material with respect to a broad accessibility.

As described before, BeLearning’s general approach to achieve these targets focuses on the semantic encoding of all content-related parts as a prerequisite for the conversion between different media types as well as the support of different representations of interactive components.

It is vital to consider the process of content production in an early stage: Even the development of “usual” high-quality multimedia content requires a high degree of technical knowledge. The necessity of the semantic encoding of mathematical contents represents another, new obstacle. The problem is aggravated when contents should be really multimedial, i.e. when extremely interactive components are included, e.g. applets and virtual space scenarios. Editing tools are necessary which effectively support the construction of interactive, semantically encoded material.

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