# Workshop on Advanced Learning Technologies for Disabled and Non-Disabled People (WALTD)

The 7th IEEE International Conference on Advanced Learning Technologies
July 18-20, 2007
Niigata, Japan
Distributed social and personal computing for learning and instruction
http://www.ask4research.info/icalt/2007/

**Sponsored by:**
IEEE Technical Committee on Learning Technology
IEEE Computer Society

**Hosted by:**
University of Electro-Communications, Japan

Workshop chairs:

Dr James Ohene-Djan - mas01jo@gold.ac.uk
Goldsmiths College, University of London,
New Cross, London, SE14 6NW
Tel: + 44 207 919 7862
j.djan@gold.ac.uk

Dr Marion Hersh - m.hersh@elec.gla.ac.uk
Department of Electronics and Electrical Engineering,
University of Glasgow
Telephone: 0141-330 4906
***m.hersh@elec.gla.ac.uk***

Workshop on Advanced Learning Technologies for Disabled and Non-Disabled People (WALTD)

The 7th IEEE International Conference on Advanced Learning Technologies
July 18-20, 2007, Niigata, Japan
Distributed social and personal computing for learning and instruction
http://www.ask4research.info/icalt/2007/

***Workshop chair(s):***
Dr Marion Hersh
Dr Dónal Fitzpatrick

***Description of background and goals***

Education should be considered a basic right. It is also vital for personal and social development, to give individuals opportunities and society a future. It should also be considered a right of every person to contribute to society to the maximum of their ability. Access to education, particularly further and higher education, increases the contribution people can make. However, many disabled people currently experience numerous barriers in accessing both education and employment and are in an enforced state of dependence, rather than being able to earn their own living and contribute to society.

There are two main models of disability: the social model and the medical model. The medical model in both its original and revised versions was developed with the World Health Organisation (WHO, 1980, 2001). Although the revised version is closer to the social model than the first medical model, an individual's impairments are still seen as a problem to be corrected. This differs from the social model, which developed out of the disabled people's movement (Barnes, 1994; UPIAS, 1976 ). It recognises the existence of impairment, but considers disability to be due to social and infrastructural barriers rather than impairment and that the problem is in society rather than disabled individuals. It has helped many disabled people to become more confident and assertive. Through the disabled people's movement they have to some extent successfully campaigned for a change in attitudes from pity to acknowledgement of and respect for difference and increased legal rights and access to all the facilities, services and goods of society. These campaigns in combination with other factors have led to some degree of recognition of the need for full social integration of disabled people and changes in legislation to promote the rights of disabled people and counter discrimination against them. However, in most cases measures to ensure implementation of the legislation and monitoring of this implementation are lacking.

Education is still a very key factor in giving disabled people opportunities for both personal development and economic independence. Currently, many disabled people undertake numerous training schemes, which do not lead to recognised qualifications or increase their prospects of obtaining satisfying paid employment and leave them feeling frustrated and angry. Disabled people are still seriously underrepresented in both further and higher education and have lower average qualifications than the population as a whole and considerably lower rates of employment. For instance, a 2001 survey for the European Blind Union found unemployment rates of blind people of 77% in Hungary, 87% in Poland, 72% in Germany, 55% in Finland and 68% in Norway (EBU, 2001).

It is therefore important to examine the barriers to increased participation by disabled people in education in order to determine ways to overcome them. The focus of this workshop will be learning technologies and the associated underlying pedagogies. Education has always used technology, from a stick for scraping letters and diagrams in the earth or sand onwards. However, the range, diversity and different media in which educational technologies can be developed are many times greater now than at any time in the past. Computer based and multi-media learning technologies have become particularly important, but there are also very important lower level technology approaches, such as textbooks. There are also questions as to whether or not multi-purpose technologies, such as laboratory equipment, should be classified as learning technologies. However, disabled people require access to both purely learning technologies, as well as such multi-purpose technologies, in order to obtain the full benefit from education. Although disabled people often experience serious barriers in accessing and getting the greatest benefits from education, there have been advances and there are examples of good practice.

In addition to questions of accessibility, there is also the issue of usability. Accessibility is about the environmental characteristics of the system input and output which either enable or prevent particular groups of users from using the system, whereas usability is the ability of the system to carry out the intended function(s) when used by particular groups of users (Federici et al, 2005).

Other important issues relate to the cultural appropriateness of the learning content and the availability of learning technologies and the associated documentation in different languages. It should be a truism that not all (disabled) learners speak English or even another European language. Related issues include the choice of icons, symbols or abbreviations to denote particular activities or carry out operations. There are also specific cultural and other issues relating to the provision of learning technologies, preferably in the appropriate national sign language for Deaf people.

There are also issues relating to learning and cognitive styles and personal preferences. This is probably best supported by a facility to customise the system, which should be easy to operate.

Themes to be discussed in this workshop include the following:

- A study of the current state of the art, including case studies and examples of good practice.
- Specific challenges: accessibility and usability of content and presentation.
- Pedagogical issues in relationship to learning technologies for disabled and non-disabled students.
- Design for all approaches or design for specific groups of learners?: different approaches to developing learning technologies for disabled and non-disabled students.
- Involving or consulting with disabled students when designing and developing learning technologies.

- Learning technologies, open and distance learning – accessibility, usability and support issues.
- Cultural issues, personal preferences and customisation.

***Three main questions addressed by the workshop***

1. What is the current state of the art regarding the development of Advanced Learning Technologies for Disabled and Non-Disabled People?

2. How are specific challenges related to accessibility and usability of content and presentation in advanced learning technologies currently being addressed and should a design for all approach or design for specific groups of learners approach be taken in the future?

3. What are the key pedagogical and cultural issues in relation to designing and implementing learning technologies for disabled and non-disabled students.

***Target audience***

The tutorial is not exclusive to, but is meant especially for the following categories of participants:

- Developers, students and educators interested in addressing accessibility and usability issues in the design of advanced learning technologies.
- Researchers who want to explore the pedagogical and cultural issues associated with addressing the needs of disabled and non-disabled students using learning technologies.
- Students and educators with minimal technical background interested in researching learning technologies as a key factor in giving disabled people opportunities for both personal development and economic independence

***Workshop Organization***

The workshop will last for 2 hours. (We would like this to be 4 hours if possible)

The workshop will consist of 3 sessions each based on one of the 3 main questions addressed by the workshop

Each session will consist of 10 minute paper presentations followed by a 10 minute interactive discussion.

***Paper Submissions***

Paper submissions can be either position papers (2 pages long) or full workshop papers, (10 pages long).  All papers will be per-reviewed.

Position papers will be published in the main IEEE proceedings of  IEEE International Conference on Advanced Learning Technologies (ICALT 2007)

All workshop papers will be published in the online workshop proceedings edited by the general workshop chairs.

### *Submission Dates*

February 5, 2007 - Paper submission
March 16, 2007 - Notification of acceptance
April 6, 2007 - Camera ready position papers
April 6, 2007 - Camera ready workshop proceedings

### *Expected Results*

The expected results of the workshop are

- Increased knowledge and understanding of the three main questions addressed by the workshop.
- The determination of the research agenda in the area of learning technologies for disabled and non-disabled people.
- The development of a network of researchers interested in this area.

### *Program committee*

Dr Marion Hersh - m.hersh@elec.gla.ac.uk
Dr James Ohene-Djan – mas01jo@gold.ac.uk
Ms Angela Engel - angela.engel@gmx.at
Dr Dónal Fitzpatrick - dfitzpat@computing.dcu.ie
Mr David Fourney - david.fourney@usask.ca
Ms Saduf Naqvi - s.naqvi@gold.ac.uk
Mr David Crombie – dcrombie@dedicon.nl

## References

Barnes, C. (1994). Disabled People in Britain and Discrimination: a case for anti-discrimination legislation, Hurst & Co., London

EBU, (2001). Survey on the employment of blind and partially sighted people in Europe (2001), European Blind Union, http://ww.euroblind.org/fichiersGB/surveymb.htm

Federici, S. et al. (2005). Checking an integrated model of web accessibility and usability evaluation for disabled people, *Disability and Rehabilitation*, **27(13)**, 781-790.

UPIAS (1976). Fundamental Principles of Disability, London: UPIAS (Union of the Physically Impaired Against Segregation)

WHO (1980). International Classification of Impairments, Disabilities and Handicaps, World Health Organisation, Geneva, Switzerland

WHO (2001). International Classification of Functioning, Disability and Health, World Health Organisation, Geneva, Switzerland

Contact Details
Please direct any questions on WALTD to

Dr James Ohene-Djan
Lecturer
Department of Computing
Goldsmiths College
University of London
New Cross London
SE14 6NW
Email: j.djan@gold.ac.uk
Tel: 020-7919-7862
Fax: 020-7919-7853

Workshop on Advanced Learning Technologies for Disabled and Non-Disabled People (WALTD)
at
The 7th IEEE International Conference on Advanced Learning Technologies (ICALT 2007) July 18-20, 2007, Niigata, Japan

http://www.icaltd.doc.gold.ac.uk/

# Mathematical working environments for the Blind: what is needed now?

Dominique Archambault[(1)], Bernhard Stöger[(2)], Mario Batu□ĩ[(2)],
Claudia Fahrengruber[(2)] and Klaus Miesenberger[(2)]

*[(1)]INOVA/UFR922,*
*Université Pierre et Marie Curie, Paris, France*
*dominique.archambault@upmc.fr*

*[(2)]Integriert Studieren,*
*Johannes Kepler Univsersität, Linz, Austria*
*Bernhard.Stoeger@jku.at*

## Abstract

Blind people encounter great difficulties in dealing with Mathematics. Based on an analysis of these problems, we shall outline possible strategies to overcome them through software support. These strategies are currently being implemented in prototypes developed for a new Mathematical Working Environment dedicated to blind pupils and students.

## 1. Introduction

The study of Mathematics has always been particularly difficult for blind individuals. Indeed we can observe that a large majority of blind pupils do not succeed in Maths studies, while the average mainstream pupil succeeds more easily. As Maths is crucial in most science disciplines, this limits study options and future job opportunities for blind people.

We assert that there is no reason that Mathematical semantics can not be understood because of blindness; rather the biggest barrier is access to Mathematical content, which can only be through speech or Braille.

Most Mathematical concepts are best explained using drawings and notes which illustrate the main content (1).

(1)

In addition, the Mathematical notation itself uses 2 dimensions in order to convey the general structure of the formula rapidly, making the semantics easier to understand. One "pictures" the basic Mathematical content at a glance, which helps reading the details more efficiently, since the role of every part of the expression is already assimilated.

(2)

When visual modalities are not available, the situation is different. Other communication channels that are available to convey Mathematical contents (audio and tactile) do not allow a person to get a rapid overview. Indeed the representations used in both cases (Speech and Braille) are intrinsically linear, which means that formulas need to be linearised (3). In most cases this linearisation generates a much longer representation, which is more difficult to understand than the graphical one. For instance in this very simple example the linear version (3) necessitates 11 symbols while the graphical one (2) requires only 7.

$$(x + 1)/(x - 1) \quad (3)$$

The number of Braille symbols is also fairly limited: there are 6 dots available which can be combined into a maximum of 64 different patterns. Multiple Braille characters are therefore needed to code most Mathematical symbols. For instance, digits 1 to 9 are usually coded with the same Braille patterns as the first 9 letters. Prefixes then indicate whether it should be read as a digit, a lowercase Roman letter, an uppercase Roman letter, a Greek letter, etc...

To reduce the length of formulas, that is to reduce the number of characters and so facilitate understanding, Braille Mathematical notations use complex strategies. For instance, in the British code, the prefix is omitted in the case of a symbol which cannot be a number (after “j”), and lowercase Roman is assumed. In Marburg (German code), the prefix is used only the first time, like a switch, indicating that any other instance of the same pattern will be of the same type. In French and Nemeth (American code) the most frequent case is always assumed (lowercase Roman), and there is a prefix before each other (upper case, Greek, etc.). There is also a special way to represent digits: adding the dot ’6’ to the corresponding letter in French, or, in Nemeth, writing the same pattern on the lower part of the Braille cell (since those symbols do not use the 2 lower dots).

In the case of fractions, block markers identify the numerator and the denominator, making it necessary to reach the fraction symbol to determine that the expression is in fact a fraction. In Italian, the numerator and the denominator markers are not the same and there is no fraction symbol. Then when the first block marker is read, the user immediately knows it is a fraction. In the same kind of idea, Nemeth uses 3 Braille characters: the beginning of fraction, the fraction bar and the end of fraction.

To further complicate things, these Braille Mathematical notations have been developed in different countries, according to the linguistic and cultural history of these countries. Therefore, while the mainstream (visual) representation of formulas is identical in every language, the same is not true for Braille notations. Indeed each Braille Mathematical notation is widely used in its zone of linguistic influence, while it is completely unknown in other countries. In other words, a Braille formula written using the British notation is not understandable by a German speaking reader. This problem is quite important since the number of available Braille documents is very small compared to the number of ordinary Maths books.

## 2. State of the Art

During the last 2 decades a number of research projects proposed some partial solutions to this problem. First a list of projects focusing on access to Mathematical literature and preparation of Mathematical information have been developed. Most of these projects aim at converting mainstream formats to Mathematical Braille. These converters are used for different purposes. The main is to facilitate the production of scientific Braille documents. For instance they allow a teacher to use a document that was prepared for mainstream students and to convert it into Braille.

Labradoor [1] (LAtex to BRAille DOOR) converts a full LaTeX document including Mathematical formulas into Marburg Braille or into HRTEX (Human Readable TeX). Then several projects have been developed to convert MathML formulas: for instance Bramanet [2] produces French Mathematical Braille, math2braille [3] produces the Braille code in use in the Netherlands, and [4] produces Nemeth. As many Braille Mathematical codes exist, it seems interesting to create a programming library which is able to handle various Mathematical codes, as well mainstream as Braille, in a unified way, so applications using it could propose the best Maths code for each user. MMBT (Multi-Language Mathematical Braille Translator) [5] was a first attempt in this direction. It supported transcriptions from and to LaTeX, MathML, French (revisions 1971 and 2001), British and Italian Braille notations. MMBT has been developed in Java, it was discontinued and is now replaced by UMCL.

UMCL [6] (Universal Maths Conversion Library) is a programming library encapsulating various converters for different Braille codes in a single library, usable through a simple and unique API. UMCL is an open-source project and is portable. It was developed in standard "C" with wrappers to different other programming languages. To make this possible without increasing the complexity, an architecture based on a MathML as central representation of the formula was developed. Currently output modules have been developed for the French notations (revisions 1971 and 2001) and Italian. Beta versions of Marburg and British code are also already available. Input modules for LaTeX and Marburg Braille are also under development.

Another project which helps to produce documents usable by visually impaired people is Infty [7]. It is a large project aiming at giving access to printed Mathematical content. It is based on a core module (InftyReader) which is an OCR specialised in Mathematical documents. It produces a topological representation of the formulas in an XML format. Then this representation can be converted into various formats: MathML, LATEX, HTML, HRTEX, KAMS, and into Unified Braille Code (English) and Japanese Braille code.

In the other directions, converters allow sighted people to access documents written by blind people. This is more difficult to process since Braille codes are context sensitive. INSIGHT [8] proposes a complete system to translate Maths documents with mixed Grade II Braille text and Nemeth code to LATEX. The system processes an image of a Braille sheet (for instance a scanned page) and recognises the Braille dots to produce an ASCII Braille file. Text and Nemeth code are automatically identified and separated to be separately translated. Finally a single LATEX document is produced to be read by a sighted individual.

Several projects [9], [10], [11] focus on better presenting Mathematical contents in speech.

Now we need some new software tools that support the work of blind users, facilitating their understanding and helping them to carry out calculations, while facilitating inclusion in mainstream environment. Indeed more and more such pupils attend to mainstream schools, so it is necessary that these tools are usable with teachers who do not have a specific knowledge of Braille. A few projects have been carried out since a few years.

The Maths Genie [12] is a formula browser that facilitates understanding of formulas using voice. It has been designed to convey the structure of the Mathematical expression as well as its contents. The graphical rendering is synchronised to the audio. The current version supports English, French and Spanish for speech, and offers facilities to add any local language provided that a speech synthesiser is available with the requested interface. A Braille output supporting Nemeth code, based on [4], is available.

Lambda [13] is a Mathematical reading and writing system designed for blind students. The main characteristic of the Lambda project is that it is built on a brand new code. This code is an XML code specifically designed for supporting the Braille transcription into 8-dot pattern national codes. Each Lambda national code has the lambda structure and a Braille character dictionary as close as possible to the official national code. Lambda comes with a dedicated editor, which includes navigation support, input functions (keyboard shortcuts, menus, tool bar). It outputs Lambda Braille, speech synthesis (Mathematical symbols are verbalised in a descriptive language), a visual presentation in a linear code (a specific font in which each Braille character is represented by a visual symbol). A graphical rendering can be displayed on demand (but it is not synchronous to input).

## 3. Strategies to overcome the problem

The strategies presented here are implemented in MaWEn prototypes that are developed conjointly by Johannes Kepler Universität Linz and l'Université Pierre et Marie Curie within the framework of the MICOLE project. These prototypes are preliminary studies for the development of a Mathematical Working Environment dedicated for blind pupils and students.

### 3.1 To support collaborative work by synchronising views

One essential idea is that new tools should support collaborative work between blind and sighted individuals, most typically in a mainstream teaching environment, where a single blind pupil needs to be able to collaborate with a sighted teacher and possibly several sighted school mates.

This requires synchronisation of 2 representations using 2 different modalities, one for the blind and one for the sighted. Documents are composite: a main textual structured content includes Mathematical expressions. In MaWEn it is not yet possible to include other kinds of objects (like images with alternative content) but this possibility will be explored if the need appears from the users, for instance in the case of reading a schoolbook. Synchronisation of textual contents in both modalities is not particularly difficult, nevertheless care should be taken that the part which is displayed in Braille always appears on the screen and is clearly identifiable so that sighted users can easily follow the work of the blind pupil.

In the case of Mathematical expressions it is necessary that each of the representations synchronised needs to be a natural representation; that is the representation the readers are used to. In the case of sighted people it needs to be the natural graphical view, while In the case of Blind readers it has to be the Braille Mathematical notation they have been taught, that is the official Braille notation in use in their environment.

Synchronisation must allow each person to point at a location on the document, in the textual part as well as in a Mathematical expression, to show it to the other, in order to highlight an idea or to explain an error. With a graphical view this pointing should be done using the mouse by clicking on the desired location. The specified location would then be highlighted on the alternative view. In the other mode the Blind user must be able to make a selected location display with a different background on the screen.

The synchronisation must also support selection. The current selection must appear clearly as well on the screen as on the alternative display (Braille). This is achieved by showing the current selection with a different background colour. On the Braille bar it is possible to underline the selection using dots 7 and 8.

Synchronisation seems essential in inclusive education. Once again it is not a particular difficulty in the case of textual contents. For Mathematical expressions, it is made possible by the use of MathML conjointly with MathML to Braille converters. Indeed the MathML can easily be displayed graphically thanks to existing software. MathML to Braille converters enable the user to access in real time to a Braille transcription of the formula displayed on the screen. We have developed a model allowing to keep the Mathematical elements described in MathML and the corresponding Braille symbols linked. This model is implemented in the UMCL conversion library and allows MaWEn prototypes to support full synchronisation between the 2 views.

Remark: in the following sections we will only focus on the Mathematical expressions.

### 3.2 Collapse and Expand sub-branches of expressions

The main obstacle for a blind person to read and understand a Mathematical expression is the length of formulas and the complexity of notations. To get an idea about these crucial problems, and to explain the concept of collapse/expand which may help to overcome them, we would like to talk on the **structural tree** of a formula. As an example, let us consider this equation:

$$L_1 = L_0 . \sqrt{1 - \frac{v^2}{c^2}} \quad (4)$$

It is an equation, with two sides: A “simple expression”, $L_1$ and a product, composed of another simple expression, $L_0$ , and a square root. The square root, in turn, is the difference between the number 1 and a fraction. The numerator of that fraction is $v^2$ , the denominator is $c^2$ .

This little discussion shows that our formula can be viewed as a tree; it is this very tree that makes up its Mathematical meaning, and that is understood by a sighted person at one glance, even if that person be not a Mathematician at all, or if that formula were even much more complex than this relatively simple example. On the other hand, the blind student will have considerable difficulty understanding the tree, and these difficulties are for sure more than proportional to the length of the formula. The blind person will have to do quite much reading forward and backward in order to finally understand this tree.

It is the idea of collapse/expand to assist the blind person in understanding the tree by presenting certain parts of it in full, while others are presented only in terms of blocks, informing the reader that more detailed information about the branch is available on request.

The above example formula (4) collapsed to the maximum possible, would be represented just by a block. Expanding this to one level, we get:

$$L_1 = L_0 . <\text{block}> \quad (5)$$

Expanding the block will finally give its content, namely:

$$L_1 = L_0 . \sqrt{1 - <\text{block}>} \quad (6)$$

When looking at the above tree expansions, it will be noticed that there are “jumps” in the expansion: For example, when expanding the right side of the equation, strictly following the tree structure would result in a block for the multiplication: $L_1 = <\text{block}>$ , and then it would be necessary to expand this block to obtain the expression showed in (5). Also, expanding the square root should yield: $L_1 = L_0 . \sqrt{<\text{block}>}$ . We did not propose to follow the structure in such a strict way because we think that this would make the process of expanding clumsy and, hence, less useful: sub-expressions of sufficient simplicity and brevity, like the left factor of the right side of our equation or the contents of the square root, should be displayed at once, without having to go through the strict expand process. It is considered an important task for the developer of a good collapse/expand algorithm to be “judicious enough” to keep these ergonomic aspects in mind.

This collapse/expand is not a new technique: It is used in “Integrated Development Environments” for quite a long time. It is implemented in projects to support blind persons in dealing with Mathematics, e.g., Maths Genie [12] and Lambda [13].

In the MaWEn prototype, we give headlines to the different blocks in order to make it easier to the user to understand the underlying structure. These headlines are mnemonic letters. To come back to our example, the formula, collapsed to the maximum possible, would be represented by the letter E, for “Equation”. Expanding this to one level, the square root is represented by the letter “Q”, so we would get:

$$L_1 = L_0 . Q \quad (5')$$

When expanding the Q, its content would be displayed using the letter “F” for fraction:

$$L_1 = L_0 . \sqrt{1 - <\text{block}>} \quad (6')$$

When looking at the above mnemonics like “E”, “Q”, “F” etc. one might ask how to distinguish them from ordinary Mathematical symbols. Indeed, a possibility of clearly distinguishing such mnemonics from

Mathematical characters must be found. As far as 6-dot Braille representations are concerned, this problem will not occur, because we shall use the mnemonics with dot 7. In case of an ASCII based Maths notation, however, other techniques need to be applied.

Another important requirement for collapse/expand support is the ability to synchronize it with the visual view. This means that, in a collaborative setting of a blind and a sighted person, a means must be found to make collapse of part of a formula visible to the sighted partner, typically, the teacher.

### 3.3 Editing functions

We do not consider it essential to use Braille Mathematical codes for inputting formulas. The main reason is that converters from Mathematical Braille to MathML are not yet available in the languages we need. It is also necessary to implement a solution which does not imply the use of a Braille keyboard, which is not available in every situation. Anyway as soon as such Braille to MathML converters will be efficiently available in UMCL, it will not be difficult to add this feature.

We propose instead a combined input scheme, where simple expressions such as numbers, variables, or polynomials can be input directly from the Braille or ASCII keyboard, while complex structures like roots, sub and superscripts, fractions etc. are to be input through commands (available in a menu and as keyboard shortcuts)

- **Numbers**: Ordinary Arabic numbers should be input directly, either through a Braille keyboard or through an ordinary qwerty keyboard. In the latter case, the number sign, which is common in many Braille codes, will be input automatically. As an alternative, input through a command should also be possible – this will prove helpful, e.g., in the rare case where Roman numbers are to be input through a standard keyboard. In any case, number input will be terminated by a space. Some caution will have to be applied when deleting or inserting digits: When a digit following the number sign is deleted, the number sign should be removed automatically provided there is no digit left. When inserting a digit it should be checked if another digit is present just after in order not to add a number sign.

- **Variables**: The same philosophy as for numbers will be applied. Special attention deserves the case where a variable consists of more than one letter. We can offer several strategies to handle this: In any case, we propose that letters input directly through the keyboard should be considered distinct one-letter variables, provided that they are not separated by spaces. Now in order to handle the case of multi-letter variables, one could either implement a command with a template (see below), or one might use spaces as separators, as is common with the well-known computer algebra system Mathematica.

- **Fences** (parentheses etc.): These symbols should be input directly through the keyboard.

- **Binary operators** (addition, multiplication etc.): The normal way of input should be via keyboard. However, commands may also be provided, creating templates like this: When the command for “Addition” is issued, an item like “placeholder + placeholder” might appear on the screen, where “placeholder” is a short symbol that can be easily recognized but still not easily confused with true Mathematical characters. For six-dot Braille codes, a double full six-dot cell would be an option. When an expression is input at the spot where the placeholder appears, then the placeholder will be replaced by that expression automatically.

- **Complex structures**: Complex structures such as sub and superscripts, roots, fractions etc. could be input through commands generating templates like in the previous example. An exception could be simple sub or superscripts, which might be input directly using the characters _ (underscore, for subscript) and ^ (caret for superscript), known from the TeX system.

To supply efficient mechanisms of selecting sub-expressions of a formula is very important, first because it is needed to realize collapse/expand support (see previous section), second, because a blind user needs to be able to select a portion of a formula in order to make it visible to his/her sighted partners.

The selection mechanisms are designed with the tree structure of an expression, as discussed in the previous section, in mind: This is because navigating through an expression will need that structure in any case. Pointing to a spot in a formula with the Braille display will select that node in the tree corresponding to the spot. Double clicking at a selected spot will select its parent node - through iterated application of that method, more and more of the expression, up to the whole one, may be selected.

There are some special cases to take care of: since not every character within a formula written in a Braille notation corresponds to a spot in its visual rendering, we need to provide for conventions on what should be selected when such a spot is pointed at on the Braille display. An example of such a character would be the opening and closing sign for a fraction, or the sign that announces the beginning of a sub or superscript. As a general rule, we propose that, when the user points at such a character, then the structure which is announced, or terminated, by that symbol will be selected. In particular, pointing at the "Begin of Fraction" or "End of Fraction" indicator will select the whole fraction, pointing at the symbol announcing a sub- or superscript will select the sub or superscript, pointing at the symbol announcing a root will select the contents of the root.

### 3.4 Manipulation support functions

Actually carrying out Mathematical calculations is even more difficult than reading and writing formulas. The problems in doing formal manipulations arise because of the complex structures that deploy during a calculation: sighted people may organise a computation such that it can be easily surveyed and navigated, and they use additional graphics to help their reasoning (see equation 1). Then there is a need for powerful editing tools that pupils can use to do calculations more easily. These tools should provide support with respect to the Braille notation itself and not to the Mathematical content.

We would like to develop our ideas on supporting blind persons in doing Mathematics by an example. Consider this exercise of multiplying two sums in parentheses:

$$(3a-5b+6c)\cdot(4a+b-3c) \quad (7)$$

The difficulties arising for a blind pupil already with such a relatively simple task were extensively analysed in [14]. Here, we shall describe how those difficulties might be reduced by implementing what we call a *Manipulation Wizard*.

To solve the exercise requires two steps: First the product must be expanded, meaning that every term of the left pair of parentheses has to be multiplied against every term of the right pair. Second, the resulting sum has to be simplified. We shall describe two wizards, one for expanding, and one for simplification, which in our example will be executed in sequence.

We begin with the expansion wizard: Every term of the left factor has to be multiplied by every term of the right one, the order being completely arbitrary. A wizard should address this by offering the various sub-multiplications to the student – (s)he is presented the factors, and needs just to enter the sub-products. By pressing the Down arrow key, the next sub-product should be automatically presented. For every sub-product, there should be an edit field to receive the calculated value from the user, e.g., in the line:

$$3a\cdot 4a=\ldots \quad (8)$$

There is an empty box after the equals sign, to receive the result $12a^2$ from the user. The wizard should collect all these results of sub-products, yielding a sum like this:

$$12a^2-20ab+24ac+3ab-5b^2+6bc-9ac+15bc-18c^2 \quad (9)$$

This sum is not yet the final result – it needs to be simplified. For this task, a *Simplification Wizard* should be designed: to simplify an algebraic sum, the following systematic procedure can be applied: Iterate through all the terms of the sum, choosing a "reference term" – this is the outer iteration. Compare the reference term to all terms coming after it, in order to find terms to be contracted – this is the inner iteration. If the reference term can be contracted with subsequent terms, collect the contractions for the resulting sum. If you do not find any successors of a reference term to be contracted with it, take the reference term into the result unchanged.

Even when strictly following this scheme, you may fall into two difficulties: First, you shall find terms succeeding a reference term that already were compared to a prior reference term, such that they do not need consideration anymore. Second, the procedure may let you view terms as reference terms which were successors of older reference terms, such that they also were already treated and are now to be skipped.

The *Simplify Wizard* addresses these difficulties by quite a simple procedure: As always, it presents you the various pairs "reference term – successor" beside each other. You may iterate through the successors with a pair of keys, e.g., Page-Up and Page-Down, leaving the reference term unchanged. You may take the next reference term with another key, e.g., the End key.

When a particular reference term is chosen, you may mark it with Control-M – this sets an opening square bracket left to it, which will remain adherent, such that, when you come across that term in the future, you will see that it was already considered. Also, it will be copied into a temporary edit buffer, allowing you to contract successors with it. Equally, when you decide a particular successor to be contracted to the reference term, then you should mark it with Control-M: This also makes an opening square bracket adhere to it, such that it can be seen as already having been used in the future; moreover, it copies the successor into the temporary buffer, to facilitate computing the contracted term.

Once a particular reference term has been fully processed, i.e., once all its successors have been considered, the sum representing the contraction, or the unchanged reference term, can be written into the temporary buffer. Once the various terms having formed the contracted sum were deleted manually, you may press the Down arrow key in order to copy the interim result into the final one, automatically clearing the temporary buffer to give room for the next reference term.

Although wizards of that kind would reduce much of the tremendous difficulties encountered by blind persons in doing Mathematics, it was argued that they are “too supportive”, which means that they take so much Mathematical work away from the pupil that (s)he might fail to understand the procedures of calculation. It is indeed an open research question how to develop software routines which, although being supportive, still leave enough responsibility on behalf of the pupil. As an example, the *Expansion Wizard* might be modified such that the pupil may carry out the iterations through the terms of the two factors by him/herself: By walking through one factor, (s(he may choose one of its terms as reference term by selecting it. In a second step, this reference term should be made constantly accessible to the pupil, while (s)he walks through the second factor in order to do the inner iteration by selecting terms of it. Once the result of a sub-product is computed, the student may issue a command to copy the result to a final sum, which (s)he may inspect after all the iterations are completed.

The ideal case would be to have a kind of “Method Base”, consisting of elementary support functions, from which more complex supportive wizards similar to the ones sketched here should be modelled through a configuration language, or, perhaps, through a wizard, in turn. Such a meta-tool should be made accessible to the teacher, or perhaps to a very advanced pupil, in order to tailor support to the pupil’s Mathematical maturity and abilities.

### 3.5 Context sensitive help for Braille codes

Additionally there is also a tremendous need for providing contextual support on the Braille Mathematical code. Braille Maths codes are normally hard to learn for a blind pupil, and almost impossible to learn for a sighted teacher. In order to support both the pupil and the interested teacher, a tool to furnish context-sensitive help for a Mathematical text written in a Braille notation would be desirable. Such a tool might display information about a character read by the Braille display, information about its meaning in Mathematical context for the blind partner, and, if possible, the black-print analogue of the character for the sighted partner. It should also offer concrete examples of its use, and an account of the important rules to be followed when using it.

## 4. Conclusion

We believe that the strategies described in this paper will effectively support the work of Blind individuals. They will be implemented in MaWEn and evaluated in school situations. One common thread with the other projects cited in the state of the art is the use of MathML. It is of tremendous importance to generalise the use of MathML in mainstream scientific documents so these documents can be easily accessed with those specialised tools.


## Acknowledgements

The MaWEn prototypes are developed within the framework of the MICOLE project, which is funded by the INFSO DG of the European commission, within the framework of the IST 2002 programme (FP6/IST/eInclusion) under the reference IST-2003-511592 STP. This paper was written with the support of the @Science project which co-funded by the INFSO DG of the European Commission4, within the eContentPlus programme (FP6/thematic network priority), under the reference ECP-2005-CULT-038137. The contents of this paper is the sole responsibility of the authors and in no way represents the views of the European Commission or its services


## References


[1] Batu□ĩ M., Miesenberger, K., and Stöger B. (1998), “Labradoor, a contribution to making Mathematics Accessible for the Blind”, In Edwards, A., Arato, A., and Zagler, W., editors, Proc. ICCHP 98 (6th International Conference on Computers Helping People with Special Needs), Oldenbourg, Wien, München.

[2] Schwebel, F. (2003). "BraMaNet logiciel de traduction des mathématiques en braille." [http://handy.univ-lyon1.fr/projets/bramanet/].

[3] Crombie, D., Lenoir, R., McKenzie, N., and Barker, A. (2004). "math2braille: Opening access to Mathematics." In Miesenberger, K., Klaus, J., Zagler, W., and Burger, D., editors, Proc. ICCHP 2004 (9th International Conference on Computers Helping People with Special Needs), volume 3118 of LNCS, pages 670-677, Berlin. Springer.

[4] Stanley, P. B. and Karshmer, A. I. (2006). "Translating MathML into Nemeth Braille Code." In Miesenberger, K., Klaus, J., Zagler, W., and Karshmer, A., editors, Proc. ICCHP 2006 (10th International Conference on Computers Helping People with Special Needs), volume 4061 of LNCS, pages 1175-1182, Linz, Austria. Springer.

[5] Moço, V. and Archambault, D. (2003). "Automatic Translator for Mathematical Braille." In Stephanidis, C., editor, Universal Access in HCI - Inclusive Design in the Information Society, volume 4, pages 1335 - 1339, Mahwah, New Jersey, USA. Lea.

[6] Archambault, D., Fitzpatrick, D., Gupta, G., Karshmer, A., Miesenberger, K., and Pontelli, E. (2004). "Towards a Universal Maths Conversion Library." In Miesenberger, K., Klaus, J., Zagler, W., and Burger, D., editors, Proc. ICCHP 2004 (9th International Conference on Computers Helping People with Special Needs), volume 3118 of LNCS, pages 664 - 669, Berlin. Springer.

[7] Suzuki, M., Kanahori, T., Ohtake, N., and Yamaguchi, K. (2004). "An Integrated OCR Software for Mathematical Documents and Its Output with Accessibility." In Miesenberger, K., Klaus, J., Zagler, W., and Burger, D., editors, Proc. ICCHP 2004 (9th International Conference on Computers Helping People with Special Needs), volume 3118 of LNCS, pages 648-655, Berlin. Springer.

[8] Annamalai, A., Gopal, D., Gupta, G., Guo, H., and Karshmer, A. (2003). "INSIGHT: a Comprehensive System for Converting Braille based Mathematical Documents to Latex." In Stephanidis, C., editor, Universal Access in HCI - Inclusive Design in the Information Society, volume 4, pages 1245 - 1249, Mahwah, New Jersey, USA. Lea.

[9] Raman T.V. (1994), “Audio Systems for Technical Reading”, PhD thesis, Department of Computer Science, Cornell University, NY, USA.

[10] Stevens R.D. (1996), “Principles for the Design of Auditory Interfaces to Present Complex Information to Blind People”, PhD thesis, University of York, UK.

[11] Fitzpatrick D. (2006), “Mathematics: How and What to Speak”, In Miesenberger, K., Klaus, J., Zagler, W., and Karshmer, A., editors, Proc. ICCHP 2006 (10th International Conference on Computers Helping People with Special Needs), volume 4061 of LNCS, pages 1199-1206, Linz, Austria. Springer.

[12] Karshmer A., Gupta G. and Gillan D. (2002), ”Architecting an Auditory Browser for Navigating Mathematical Expressions”, In K. Miesenberger, J. Klaus, and W. Zagler, editors, Proc. ICCHP 2002 (International Conference on Computers Helping People with Special Needs), volume 2398 of LNCS, pages 477-485, Linz, Austria. Springer.

[13] Schweikhardt, W., Bernareggi, C., Jessel, N., Encelle, B., and Gut, M. (2006). "LAMBDA: a European System to Access Mathematics with Braille and Audio Synthesis.", In Miesenberger, K., Klaus, J., Zagler, W., and Karshmer, A., editors, Proc. ICCHP 2006 (10th International Conference on Computers Helping People with Special Needs), volume 4061 of LNCS, pages 1223-1230, Linz, Austria. Springer.

[14] Stöger B., Batu□ĩ M. and Miesenberger K. (2004), "Mathematical Working Environment for the Blind Motivation and Basic Ideas" In Miesenberger, K., Klaus, J., Zagler, W., and Burger, D., editors, Proc. ICCHP 2004 (9th International Conference on Computers Helping People with Special Needs), volume 3118 of LNCS, pages 656-663, Berlin. Springer.

Workshop on Advanced Learning Technologies for Disabled and Non-Disabled People (WALTD)
at
The 7th IEEE International Conference on Advanced Learning Technologies (ICALT 2007) July 18-20, 2007, Niigata, Japan

http://www.icaltd.doc.gold.ac.uk/

# Vocational Training and the Workforce

## - disability policy adapted for vocational training and work integration –

by

Marina Muscan
League for the Defense of the Disabled People's Right from Romania
marina.muscan@rosal.ro / marina.muscan@gmail.com

and
Ileana Hamburg
Institut Arbeit und Technik, Wissenschaftszentrum Nordrein-Westfalen, Germany
hamburg@iatge.de / hamburg@iat.eu

**Abstract:**

*Disability policies target a large and heterogeneous group of persons. According to an OECD study in the twenty countries studied, on average about 14% of the working-age population classify themselves as disabled. About one-third of the group of working-age disabled people are severely disabled. Persons with congenital disabilities form a minority of usually less than 10% of the entire group of working-age people with disabilities. Vocational rehabilitation and training is predominantly offered to people below age 45, thus partly explaining the age bias in the disability benefit programs. In this paper after a presentation of some disability policies and an example of s disability police oriented to learning Web-design, an example of a project is done aimed at development of vocational training models for small and medium-sized companies (SMEs). These models are social-oriented and based on e-Learning.*

### 1. Disability policies

Disability policies target a large and heterogeneous group of persons. According to an OECD study in the twenty countries studied, on average about 14% of the working-age population classify themselves as disabled. About one-third of the group of working-age disabled people are severely disabled. Persons with congenital disabilities form a minority of usually less than 10% of the entire group of working-age people with disabilities. As one would expect, the prevalence of disability gradually increases with age: disability prevalence rates in the 50-64 age group are around 25%, but only 10% in the 20-49 age range. Some of this increase is explained by the fact that a large part of disabling conditions have a permanent character. The level of education also plays an important role: disability prevalence rates are significantly higher among groups with lower educational attainment, with an OECD average of 19%, compared to 11% among the better educated.

Disability policy, in general, faces twin but potentially contradictory goals. One is to ensure that disabled citizens are not excluded: that they are encouraged and empowered to participate as fully as possible in economic and social life, and in particular to engage in gainful employment, and that they are not ousted from the labor market too easily or too early. The other goal is to ensure that those who are or who become disabled can benefit from income and security: that they are not denied the means to live decently because of disabilities that (may) restrict their earning potential. How to reconcile these twin goals has yet to be resolved.

There are indications that the assessment of disability and work capacity is becoming more difficult especially because many countries had to face the problem of population aging that also causes the reduction of the working capacity. The situation has gradually worsened with the widespread increase in the share of more difficult to diagnose diseases, such as new mental illnesses as well as many physical stress-related conditions like lower back pain. It is difficult not only to diagnose these disabilities and to assess their implications for work capacity but also to predict how these conditions may evolve in the future. The increasing proportion of people with mental or psychological problems among the recipient population is a major concern in many countries. Today, mental and psychological problems comprise around one-quarter or even one-third of the stock and flow of disability benefit recipients in most countries where such data are available. The younger the recipient population, the higher, by and large, is the share of recipients with mental conditions. This situation reveled by the ODC Study rise a question regarding the capabilities of the human resources in long-term employment.

Integrating the disability program into the retirement program, as was done in some countries, however, has disadvantages. It implicitly suggests that a disability benefit is a permanent pension payment, and it does so not only to the benefit applicant or recipient. For the pension insurance system itself, it will be difficult to operate an efficient disability program because two very different risks, disability and old age, are mixed up. Empirically, it is evident that countries with linked disability/old-age schemes have considerably older recipient population.

During the 1970s and 1980s, early retirement programs were introduced with the dual aim of alleviating the labor market problems of older workers. Those countries in which (early) retirement seems to play a very important role for people with disabilities as an alternative route for labor force exit, like Austria or Portugal, are also countries in which disability benefit recipients are overwhelmingly aged 45 and over. It seems that generous early retirement schemes pull older workers out of the labor market, without lowering the pressure on the disability benefit scheme. There appears to be a correlation between generous early retirement and (de facto) age profiling in the disability benefit regulations. This creates an early exit culture, which increases the burden on both the retirement and disability scheme.

In this context it is important to observe a certain imbalance in incentives. It is (at least moderately) disabled people who would potentially be in a position to "choose" between either a disability or an early retirement benefit - be it a free choice or employer-forced coercion. For people without measurable disability, who could not pass the medical test for a full disability benefit, the situation is very different. For this group, relative incentives between disability and early retirement programs in terms of benefit levels.

On the other hand, women are generally under-represented on insurance and over-represented on means-tested benefit programs. This is not the case in some schemes with individual entitlement for the entire disabled population, in which women below age 45 have much higher inflow rates than men.

Mental and psychological problems are responsible for between one-quarter and one-third of disability benefit recipe levels, and for a considerable portion of the increase in those levels.

Vocational rehabilitation and training is predominantly offered to people below age 45, thus partly explaining the age bias in the disability benefit program, but sheltered and supported-type employment programs also tend to benefit mostly young severely disabled people. While the approach to vocational rehabilitation and training differs markedly between countries, this type of intervention is usually used too little, and often initiated too late. More can be done to involve the employers in this process. The average per capita cost for vocational rehabilitation and training is low compared to the average cost of a disability benefit. Provided that such intervention secures permanent employment, investments should pay off within a short period. Societies need to change the way they think about disability and those affected by it. The term "disabled" should no longer be equated with "unable to work". Disability should be recognized as a condition but it should be distinct from eligibility for, and receipt of, benefits, just as it should not automatically be treated as an obstacle to work.

Many societies have to design individual work/benefit packages so these work/benefit packages could cover all the cases mentioned above including people who are suffering from mental dieses but who can perform activities that are needed on the labor market. Merely looking after the financial needs of disabled people through cash benefits is insufficient; this would still leave many excluded from the labor market and sometimes even from society more generally. Therefore, each disabled person should be entitled to a "participation package" adapted to individual needs and capacities. This package could contain rehabilitation and vocational training, job search support, work elements from a wide range of forms of employment (regular, part-time, subsidized, sheltered) and benefits in cash or in kind.

In more than one-third of the countries, policy is based on a mandatory employment quota, usually written down in a special act on employing or promoting the employment of disabled people. According to such regulations, employers are obliged to have a certain proportion of disabled people among their staff: 7% of the workforce in Italy, 6% in France and Poland, 5% in Germany, 4% in Austria, 3% in Turkey and 2% in Korea and Spain. In all countries these quotas relate to both the public and the private sector, but only apply to employers with a certain number of employees - the minimum being 300 employees in Korea, 50 employees in Spain and Turkey, and 15-25 employees elsewhere. Some countries allow for double or even triple counting of severely disabled people.

Vocational rehabilitation and training can in many cases be critical to achieve or secure employment. A person becoming disabled may, even after completion of the medical rehabilitation process, not be able to continue to work in the previous occupation. This person may need additional vocational counseling and training, ranging from smaller interventions, including, for instance, initial needs assessment, to training of several years (e.g. a full university curriculum).7 Similarly, a disabled person trying to enter the labor market for the first time may need additional vocational training at an adult age. Countries have very different approaches to satisfying these needs, and large variation exists as to how often, at what stage of the process, and with how much financial input such interventions occur.

A most important issue is the timing of vocational intervention. Even if the need for intervention becomes apparent at an early stage of the sickness process, vocational measures would typically be launched at a rather late stage. There are a few countries, most importantly Sweden and Germany, in which vocational intervention starts early and is implemented promptly.

**2. Accessible Web-design and End-users**

Learning web-design can be a part of the vocational training especially because by acquiring this kind of skills the disabled people can be involved into the very process of creating accessible web pages for disabled users. Therefore the end user can be involved in the creation and the decision making process also. For many Flash designers, the single greatest challenge to understanding accessibility is how to best appreciate the experience of people with disabilities. A web designer's inherent talent is an ability to perceive the world in a unique visual way. The skill of the web designer allows him/her to view, conceptualize and translate visual information into layout and graphics. To understand accessibility and implement it in practice is to ask designers to set their visual skills aside. The first thing to do when addressing accessibility is to step outside of our frame of reference and consider the perspective of users with disabilities. By default, text objects in a Flash movie are read by screen readers. Screen readers are also able to identify buttons and movie clips with attached scripts. Screen readers, however, cannot look at a graphic element on the screen and determine its meaning. It is up to the designer to assign a text description of any graphic or animated elements in a Flash movie. This information can be assigned via either the accessibility panel or Action-Script. The following set of key concepts provides designers with the fundamentals to understanding what makes an accessible control in a Flash movie.

- Labels – the flash content has to have this characteristic in order for the screen reader to relay the information to the user.
- Role – also the designer has to describe the role of the flash content within the web-site
- State – it has to be specified the state of the flash content (on/off)
- Structure – the designer has to define the structure of the flash content in order to make it accessible for the final disabled user.

Developers creating accessible Flash must meet the following minimum requirements:

- Macromedia Flash Player 6 or later
- Windows 98, 2000 or XP
- Microsoft Internet Explorer 5 or later
- Screen readers:
    - GW Micro Window Eyes 4.2 or later

- Freedom Scientific JAWS 4.5, 6.1 or later
- IBM Home Page Reader 3.04
- Dolphin HAL 6.50
- KDS PC Talker (Japan)

The release of Macromedia Flash MX and Flash Player 6 marked the first accessible versions of the Flash platform. This version of the player serves as a minimum requirement for accessible Flash content.

Here's how rich media content is passed from the web page to the screen reader. Flash uses Microsoft Active Accessibility (MSAA) to deliver information about Flash movies to screen readers and other assistive technologies. MSAA operates as the go between for the Flash player and the screen reader. The Macromedia Flash Player creates a list of objects on the screen and records them on the MSAA "data tree". The screen reader will then read this list as it encounters Flash content. As changes are made to the screen, the MSAA data tree is updated. Changes to the movie prompt the screen reader to return to the top of the movie and commence reading through the list again. By default, text objects in a Flash movie are read by screen readers. Screen readers are also able to identify buttons and movie clips with attached scripts. Screen readers, however, cannot look at a graphic element on the screen and determine its meaning. It is up to the designer to assign a text description of any graphic or animated elements in a Flash movie. This information can be assigned via either the accessibility panel or ActionScript. Some properties, such as "Make Child Objects Accessible" or ".forcesimple" have no counterpart in HTML. Designers will need to rely on information in this document as well as information found on the Macromedia Accessibility Resource Center to learn more about these properties and the associated techniques. Screen readers and MSAA shape the experience of Flash content for users with visual disabilities in ways that are often quite unfamiliar to sighted designers. Given that screen readers always start from the top of the movie and can only read one thing at a time, there are some complex forms of Flash content that simply cannot be made accessible. For example, many simulations require users to attend to several objects at the same time. Decisions must be made based on multiple factors and relayed back to the simulation quickly. This type of multitasking activity may be easy to do in the real world for someone who is blind, but can pose a real challenge while using a screen reader. (Regan, 2005, [5])

Macromedia Flash allows authors to create these types of controls. Also, others technologies such as SVG and Ajax have generated interest in the last couple of years because they allow the creation of accessible web pages for disabled users.

Text equivalents should be provided for an entire movie in cases where the movie can be conveyed using a single text equivalent. Examples of this include movies that show a simple animation, banner ads or complex movies that cannot otherwise be made accessible. The text equivalent should be placed in the name field. It is generally advisable to make the contents of the name field short and focused in order to describe the function of the movie. The description field can be used for longer descriptions. However, be aware that both JAWS and Window Eyes read this content automatically rather than upon user request. As a result, long descriptions used in this field can result in a tedious listening experience. In cases where a single text equivalent is used for an entire movie, the child objects of the movie should be made inaccessible. This will prevent animations within the move from causing frequent updates to the screen reader. It will also facilitate automated testing of the content for accessibility.

To provide a text equivalent using ActionScript, a new object must be created for each instance and then the accessibility information is assigned. Once the name value has been assigned, the accessibility objects must be updated. This is done once for all objects when a change is made. It is not necessary to update each instance of the object. Notice the sample code below includes a line to create the new object for the entire movie. Next, the value is assigned for the name property and then the child objects are made inaccessible using the forcesimple property.

A complete list of the ActionScript properties is shown below with the corresponding fields on the accessibility panel.

```
_root._accProps = new Object();
_root._accProps.name = "name of the object";
_root._accProps.forcesimple = true;
Accessibility.updateProperties();
```

This language can be read by screen readers therefore disabled people (especially blind or partially sighted people) can learned it and then use it in order for them to create accessible web-page content. For deaf, or people with hearing impairments this language script can prove a very useful tool also because they also can be involved into web-design creation as both designers and end-users.

By using this approach a directly accessible products will be crated that allow a person with a disability to operate all on-screen controls and access all content without relying on assistive technology at the end stage of the vocational training process. The designers will use features that enlarge all controls and on-screen text. The designers will evolve together with the end-users.

Also, for people who cannot operate a key-board or a mouse, a basic speech recognition system can work very well in web design especially if the user knows the programming language needed for using the Action Script. The free CVoiceControl (which stands for Console Voice Control) started its life as KVoiceControl (KDE Voice Control). It is a basic speech recognition system that allows a user to execute Linux commands by using spoken commands. Therefore a CVoiceControl replaces KVoiceControl. The software includes a microphone level configuration utility, a vocabulary "model editor" for adding new commands and utterances, and the speech recognition system. CVoiceControl is an excellent starting point for experienced users looking to get started in ASR. It is not the most user-friendly system, but once it has been trained correctly, it can be very helpful. This Voice Recognition System can be used in the design of accessible web pages under Linux system using StarOffice 5.0., or Open Office or the Mozilla browser editor called Composer which is imbedded within the browser itself. The Composer has also HTML Source Editor that can be accessed and which allows the web-designer to edit a web-page by following the well known steps as it follows into the next html coding scheme generated within the Mozilla Composer:

`<html>`

`<head>` (which is the header of the page)

`<meta content="text/html; charset=ISO-8859-1"` – which will a allow the search engine to identify the page on the Internet

`http-equiv="content-type">` - which represents the content of the page as it is viewed by a Search Engine

`<title></title> -` title of the web-page

`</head>`

`<body> -` the main body of a web-page

`<br> -` break insertion within the body of the web-page

`</body> - -` the main body of a web-page which follows after the break
`</html>`

The HTML language can be learned by disabled users with the assistance of web-designer and they can use it afterwards to create better web-pages that respond to the special needs of the disabled people. They will learn how to design accessible web-pages relying very little on accessible technology. They will learn how to adapt themselves to the existing technology.

**3. Social-oriented vocational training for SMEs based on e-Learning**

In the last ten years many countries have known the process of population aging, therefore within the various organizations are old employees who are suffering for various disabilities related with age and work conditions as poor sight or deafness. Therefore more and more enterprises have to make the environment accessible for their aging workers. As a result of the accessible making process the workers have to be trained in order for them to be able to use the accessible tools. Also, SMEs as well as other type of enterprises have to adapt to the changes in the active work force.

Some of these aspects will be considered within the ongoing e-Learning project SIMPEL and the Grundvigt project BASKI.

The SIMPEL Project proposes a new concept of vocational training concept that should take into consideration the problem of the aging workforce that confronts itself with disabilities and based on e-

Learning. The vocational training offered by the SIMPEL Project responds both to the needs of the workforce and to the needs of the employers even before a non-working period is established - in which a disabled employee cannot work anymore due to his/hers disability. During this project we propose a vocational training that will take place within SMEs, in the benefit of the workers, before the process of early retirement starts due to disability.

The use of e-Learning in a social sense means not only telling the people that the Internet and the new technologies are important but showing it too in a practical manner. Digital inclusion means more than showing people how to surf the web or to send e-mail. The e-Learning can be used in working life (corporate training sector) having a main advantage in supporting elimination of the border between working and learning. It means that learning can be better integrated in the working life.

The main objectives of the project SIMPEL are the analysis, structuring, dissemination and valorization of successful training implementations based on e-Learning in forms of training models for SMEs taking into consideration social aspects. The training approaches are life-long-learning oriented and differentiated according to the target group concerned. The models are developed for groups of SMEs having similar profiles.

The models will be tested within seminars with SMEs managers, staff, SMEs trainers and consultants. A special activity of SIMPEL will be dedicated to disabled workers from a such group who need to have access to web-content on day to day bases. It is planned to organize special cooperative training sessions for aging disabled staff and experts from web-design organizations.

The main methods of work in the project are case studies that will be conducted within various SMEs, expert reports, a Website in different languages, publications and conferences/workshops, a BSCW server, for the communication between the project partners, a Model-based virtual room for the communication with external evaluators and within the networks used within SIMPEL.

Expected results:

- Structured results of e-Learning projects aimed at SMEs,
- Sustainable models of e-Learning in SMEs and guidelines,
- Valorization and implementation plans for them,
- Multilingual Website in different languages containing project results, conference papers, e-Learning models (“best practice”), external and internal evaluation reports.

The e-Learning model presented within the SIMPEL Project is based on a network and the quality of education provided by this type of education depends by the quality of all the components of the network even if we take into account the human or the technological part of the network.

This is an important social and economic aspect because most people with disabilities of working age in Europe are out of the labor market and heavily dependent on disability benefits or often employed in low-skilled and low-paid jobs due to their poor basic education.

One suitable solution for SMEs is to build communities of practices +supported by virtual distributed learning environments to share knowledge, to apply best practices in technology-enhanced learning and to develop business-oriented models of e-Learning for them. Such forms of co-operation could stimulate new experiments, new actions and new directions for learning.

“Communities of practice are formed by people who engage in a process of collective learning in a shared domain of human endeavor..”(Wenger, 2004)
They trace their roots to constructivism (Palloff al., 1999) involving open-ended questions, learning in social and physical context’s of real-world problems and using collaboration. and cognitive tools.

A community of practice is characterized by:

- a shared domain of interest of its members, a commitment of them to this domain and a shared competence that distinguishes members from other people,
- the community means members interact around common actions and ideas,
- the practice means members of a community are practitioners with different levels of expertise and they develop a shared repertoire of resources.

A growing number of associations are seeking such ways to focus on learning through reflection on practice because they need to offer high-value learning activities.

Communities of practice are voluntary and so they have to create interactions that make them alive, attractive and engaging for members. New technologies like the Internet extend the interactions within communities of practices beyond geographical limitations and make possible the building of virtual ones.

Learning in these kinds of distributed environments present numerous challenges. Some of them include building trust and common ground, coordinating the communication and work activities within the distributed environment and controlling the discussions.
Some specific problems, which emerge in distributed learning environments, are the following:

- Social presence: because of the limited communication channels it is rather difficult to know always who is the learning partner, what he or she does and where he or she is. A method of increasing the social presence is to structure the learning environment in virtual rooms and to build in guarantees of trusted or reliable member identities.
- Cognitive orientation: often it is difficult to understand what subject is discussed and what the structure of the learning material is. The development of a well established learning community that uses the environment, which can facilitate these understanding problems. (Covey, 1989), (Hamburg et al., 2002).
- Communication and plots that usually go off smoothly in “face to face“ situations sometimes can split in a distributed learning environment. The carrying out of learning protocols within the use of learning environment could be a solution in such a case.

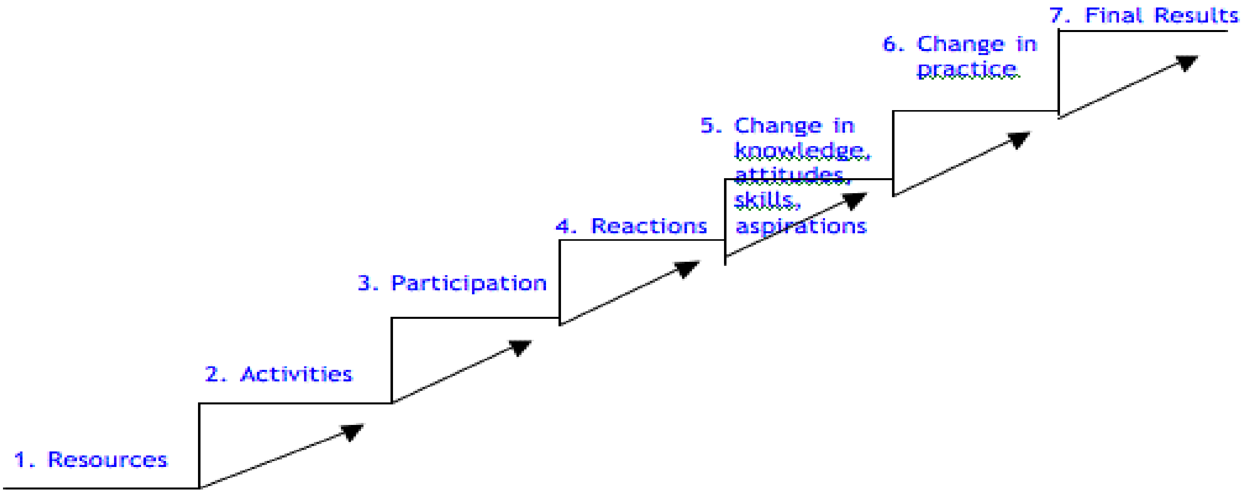
In order to solve these problems meeting are priory arranged between disabled workers from a SMEs and flash developers who work in other enterprises and who are part of this program in order for them to discus problems that appear during the knowledge transfer process between them and the SMEs workers.
Besides of offering blend-learning solution we can build a learning community, which can offer also information, and social knowledge by adding simulated social scenarios to a common learning community. These social scenarios are based on the fact that the interactivity one of reasons because e-learning communities exists.

In order to establish the final effectiveness of the vocational training model proposed by the SIMPEL Project an evaluation system will be put in motion during the last stage of vocational training. The approach proposed to evaluate the effectiveness of e-learning strategies can be considered as a mix of the decision-making, goal-free, and expert evaluation models. More specifically, the evaluation approach is framed by Bennett’s (1979) system of criteria for measuring programme impacts (Fig. 1). According to Bennett’s systems of criteria, each hierarchy of impacts correspond to a hierarchy of evidence. That hierarchy of evidence includes the following aspects: (1) Human and financial resources; (2) Activities developed; (3) Participation; (4) Reactions; (5) Change of knowledge, attitudes, abilities, skills and aspirations; (6) Change of practice; and (7) Final results.

Since it is intended to be utilize this framework for measuring the effectiveness of e-learning strategies, it is considered appropriate to aggregate into three the last five stages of Bennett’s hierarchy:

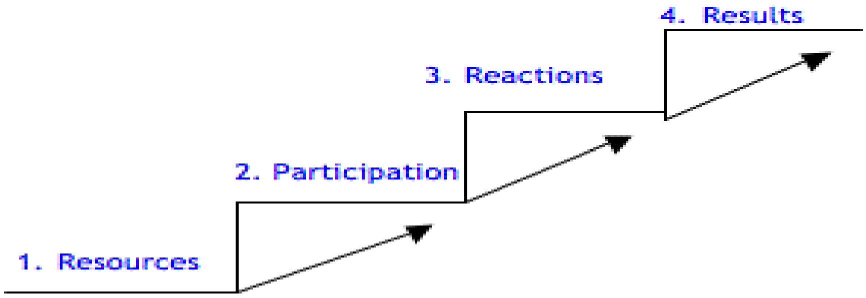
1. Participation (level 3);
2. Reactions (level 4);
3. Results (levels 5,6, and 7).

**Figure 1 - Bennett’s hierarchy of evidence – acceptance process**




In addition to the aggregation of the last five of Bennett's levels, participation is conceptualized as a set of stakeholder interventions in each phase, aspect, and activity of the e-learning programme. Similarly, reactions are taken as the target individuals responses to each phase, aspect and activity of the e-learning programme. Taking these changes into consideration, Bennett's hierarchy as applied to evaluating the effectiveness of e-learning strategies can be transformed into a 4-level hierarchy of evidence: (1) Resources, (2) Participation, (3), Reactions, and (4) Results (in terms of acquired knowledge, skills, and behaviour) (Fig.2).

**Figure 2 - Adapted from Bennett's hierarchy of evidence – acceptance process**




A valorization process will be implemented during the project. This valorization will have two levels:

1. Valorization of the e-Learning models by discussing their adaptability and their implementation in SMEs at workshops for SMEs together with national SME organizations in each partner country,
2. Valorization of the models through the e-Learning networks where project partners are active members (D-ELAN in Ger-many, etc),

Two goals will be achieved by starting this two stages valorization process:

1. The SMEs managers will understand better the necessity of this project and they will support its implementation in their own organizations having a better understanding of the final results of this project. They would have accomplished the entire acceptance process, which is shown in Bennett's scheme presented above and therefore they will be willing to implement this project and support it until its final results will be achieved.
2. E-Learning networks will be started during this project in which many social human structures will be developed. First we will have the "knowledge network" formed by people who will share knowledge between companies, then we will have the "decision making network" formed by mangers who belong to different companies and who will learn how to share human and knowledge resources based on the principle of "good faith". We will have two human networks that will depend on one another. Last but not least we will have the computer network that is necessary in the e-learning. Therefore, we will have an integrated network system of e-Learning with a human factor that passed the entire process of acceptance mentioned above and who is willing to take part in this e-Learning process.

By helping their employees to learn web-design without relying too much on accessible technology the managers of the SMEs will reduce the cost of accessibility and will help their employees to learn how to adapt to a little accessible work environment which will allow them to be able to adapt faster to very different working conditions. They will be able to adapt to the society learning how to adapt their needs to a technologized environment which is designed to serve the needs of all (disabled or non-disabled).

In looking for a suitable platform to foster the building of our community of practice and to facilitate the processes of scenario- and model-building, the SIMPEL consortium decided on Moodle. The reasons for this decision are, that Moodle was developed with the explicit intention to support a social constructionist framework of education. Pedagogical and didactic considerations led the technological development and not – as in the case of the majority of learning platforms – the other way round. Consistent with this approach, the system includes a multitude of collaborative tools, such as forums, chat rooms, polls, wikis, workshops with peer-to-peer assessments, collaborative books and many more.

**Figure3: The Use of Moodle in the Project SIMPEL**


Moodle encourages collaborative work also by providing a differentiated group mode and the ability to network course leaders/trainers. In addition, the platform is extremely flexible and easy to use for beginners. At the same time, it is "scaleable" to accommodate complex learning and teaching scenarios. The market is paying its tribute to these advantages: Moodle is presently the fastest growing openSource LMS worldwide and it even has found entry in the world of SMEs.

**4. Conclusions**

In this paper we presented an attempt which supports the e-inclusion by understanding that digital divide is a multidimensional phenomenon, which include many different drawbacks. Social-oriented training and learning how to develop technologies by end-disabled users are good policies to fight mental problems in this context.

Learning web-design for example can be a part of the vocational training especially because by acquiring this kind of skills the disabled people can be involved into the very process of creating accessible web pages for disabled users. Therefore the end user can be involved in the creation and the decision making process also. By helping their employees to learn web-design without relying too much on accessible technology the managers of the SMEs will reduce the cost of accessibility and will help their employees to learn how to adapt to a little accessible work environment which will allow them to be able to adapt faster to very different working conditions and to the society.

**References:**

[1] *** "Transforming Disability into Ability: Policies to Promote Work and Income Security for Disabled People", OECD (Organization For Economic Co-Operation And Development), France, 2003, (http://www.oecd.org/document/14/0,2340,en_2649_35288841_35290126_1_1_1_1,00.html). p. 23 – 53

[2] Eduardo Figueira, "Evaluating the Effectiveness of E-Learning Strategies for Small and Medium Enterprises", European Seminars - Exploring models and partnerships for e-Learning in SMEs", 2003, (http://217.34.108.131/ict_smes_seminars/papers.html)

[3] Dougiamas, Martin, Interview Oct. 2006, http://www.stevehargadon.com/2006/10/interview-with-martin-dougiamas.html

[4] **** E-Learning Framework Technical White Paper February (2003): Introduction http://www.sun.com/products-n-solutions/edu/ whitepapers/pdf/framework.pdf

[4] Ionescu, Adina / Hamburg, Ileana / Muscan, Marina, 2006: Supporting the development of basic skills of people with multiple impairments by training and new technologies. In: Conference on Assistive Technology for Vision and Hearing Impairment - CVHI' 2006, EURO-ASSIST-VHI-4: Kufstein, Austria, 2006, 18 july - 21 july. CD-ROM. Glasgow: Univ., p.10

[5] Muscan, Marina / Hamburg, Ileana / Ionescu, Adina, 2004: Linux - the use of internet for people with visual impairments. In: Hersh, Marion (ed.): Conference on Assistive Technology for Vision and Hearing Impairment - CVHI' 2004, EURO-ASSIST-VHI-3: Granada, Spain 2004, 29 june - 2 july. CD-ROM. Glasgow: Univ., 6 p.

[6] Attwell, G./Dirckinck-Holmfeld, L./Fabian, P./Kárpáti, A./Littig, P. (2003): E-Learning in Europe – Results and Recommendations. Thematic Monitoring under the LEONARDO DA VINCI Programme. Report. *Impuls 010*. Bonn.

[7] Hamburg, I./Lindecke, Ch. (2004): E-Learning für kleine und mittlere Unternehmen: eine Untersuchung europäischer Projekte. In: Pangalos, J./Knutzen, S./Howe, F. (Hrsg.): Informatisierung von Arbeit, Technik und Bildung: Kurzfassung der Konferenzbeiträge; GTW-Herbstkonferenz, 04./05. Oktober 2004. Hamburg: Techn. Univ., pp. 159-162.

[8] Schoemaker, P.J.H. (1991): When and how to use scenario planning: A Heuristic Approach with Illustration. Journal of forecasting, 10, pp. 594-564.

[9] Johnson, C. M. (2001). A Survey of Current Research on Online Communities of Practice. Internet and Higher Education, 4, 45-60.

[10] Hamburg, I./Lindecke, Ch. (2005): Lifelong learning, e-learning and business development in small and medium enterprises. In: Szücs, A./Bo, I. (eds.): Lifelong e-learning: bringing e-learning close to lifelong learning and working life; a new period of uptake: proceedings of THE EDEN 2005 Annual Conference, 20-23 June.

[11] Palloff, R.M. and Pratt, K. (1999), Building Learning Communities in Cyberspace: Effective Strategies for the Online Classroom, Jossey-Bass Publishers, San Francisco

[12] Bob Regan, “Best Practice for Accessible Flash Design”, Macromedia White Paper, San Francisco, 2005, (http://www.adobe.com/resources/accessibility/best_practices/best_practices_acc_flash.pdf) p. 5 – 9

[13] David Slater, “Practical Evalution Interventions in Understanding Informal Learning within SMEs”, European Seminars - Exploring models and partnerships for eLearning in SMEs”, 2003, (http://217.34.108.131/ict_smes_seminars/papers.html)

Workshop on Advanced Learning Technologies for Disabled and Non-Disabled People (WALTD)
at
The 7th IEEE International Conference on Advanced Learning Technologies (ICALT 2007) July 18-20, 2007, Niigata, Japan

http://www.icaltd.doc.gold.ac.uk/

# ACCESSIBLE E-BOOKS FOR DISABLED PEOPLE

## STRUCTURED DESIGN OF ONLINE BOOKS ASSURING ACCESS TO E-LEARNING

**Author: Michael Puehringer**
E-Mail: michael-p@gmx.at
University of Linz

## ABSTRACT

The aim of this paper is to illustrate Structured Design of Documents (SDD) with special focus on print disabled readers in terms of defining an applicable meta-data formatting specification for publishing companies ensuring accessible e-books meeting the needs of print disabled readers. **Print disabilities** are impairments that prevent people from holding printed materials or from reading independently for themselves standard print due to a visual, perceptual or physical disability. SDD can also be regarded as the prerequisite for E-Learning whose foundations are electronic documents.

This means that **Advanced Learning Technologies** in the context of accessibility are adaptive to the disabilities and individual preferences of learners who need to access their learning resources in their preferred medium.

The ultimate benefit of SDD lies in the fact that an accessible rendition of the document for print disabled persons is being produced. Addressing SDD in turn gives rise to Multi Channel Publishing (MCP) which means, publications are chosen out of a

content pool for a specific target audience, the appropriate content objects are assembled and a rendition is produced and published via multiple channels - like paper, web site, portal, e-Book, CD/DVD, PDA, wireless - to reach the target audience.

## 1. INTRODUCTION

Gutenberg's invention of the movable type entailed pervasive changes as this principle made it possible to widely distribute information fast and to many people simultaneously for the first time. Furthermore the copying of texts was facilitated and also the costs involved were reduced.

However some parts of the population thirsty for knowledge were excluded: Denials on the community of the blind were inherently imposed but this changed with the aid of embossed letters for tactile printing. From now on blind people were enabled to gather access to information requested.

As the information technology era is heralded computers, electronic communication and the Internet become predominant in our daily life giving rise to plenty of problems. Many people with disabilities stand to be victims of the Digital Divide. Therefore "Access" issues need to be taken into account as new technologies are developed and particularly with regard to electronic books new requirements are to be met ensuring **accessibility**.

The way information is retrieved by blind persons changed dramatically due to the advent of digital representation of information - the Braille display generally counteracts that burden. Nevertheless some other parts of disabled people were still segregated; such as visually impaired persons: Print disabilities are impairments that prevent people from holding printed materials or from reading independently for themselves standard print due to a visual, perceptual or physical disability. These disabilities include blindness, visual impairment, but also dyslexia, severe arthritis and other types of learning disabilities or reading difficulties.

## 2. DISABLED PEOPLE SHOULD HAVE ACCESS TO THE PRINTED WORD

It is often regarded as one of the strengths of the Internet that it opens up channels of communication and provision of access to information for people who have previously been excluded from full participation in the economic and social life of the country. Demand for access to the Internet and consequently access to information by people with disabilities is steadily increasing and now seen as a human rights issue. While physical disabilities inhibit keyboard use, visual impairment inhibits screen use and learning disabilities prevent large numbers of users from participating in the benefits of the Internet and its rich resources.

Internet accessibility is important to allow all people in the community full participation in communications systems, education, employment and other economic opportunities regardless of their physical capacity (Maharey and Swain 2001).

## 3. STRUCTURED DESIGN OF E-BOOKS AND MULTI CHANNEL PUBLISHING

As E-Books saw the light of day new obstacles were imposed on disabled people. Therefore new requirements need to be taken into account with regard to electronic books ensuring an accessible rendition of the document. Certain guidelines have to be adhered to in order to **retain the structural design** of the original layout and to assure an accessible output version of the document. This means that the textual elements a book comprises (figures, tables, lists, index entries, headings, links, stanzas, etc.) are to be indicated as such already during the layout process. Otherwise non-accessible plain text outputs would be generated.

Thus the subject of this paper deals with Structured Design of Documents (SDD) with special focus on visually impaired readers paving the way for Multi Channel Publishing (MCP) in terms of defining an applicable metadata formatting specification for publishing companies wishing to distribute their books via electronic media.

Meta-data is information that describes or classifies other information. It is also described as structured, descriptive information. Metadata elements are the individual parts of a metadata schema, used to describe individual characteristics of a resource and to give the description its structure.

MCP means, publications are chosen out of a content pool for a specific target audience, the appropriate content objects are assembled and a human-readable rendition is produced which is published via multiple channels - like paper, web site, portal, e-Book, CD/DVD, PDA, wireless - to reach the target audience.

Additionally the author's specification gives rise to process automation within the publishing companies which lies in the fact that the layout of the book has to be designed just for one time and may be exported to any format supported by the DTP tools (e.g. PDF, LaTeX, XML, HTML), retaining the structural design of the original layout; e.g. captions have to be at the same position both in the printed and in the HTML version. It is not acceptable to author separate documents for print and online delivery. Both instances must be derived from a single structured document, XML facilitates this process.

## 4. DEVELOPING STRUCTURE DEFINITIONS FOR CONTENT OBJECTS

Instead of creating formatting tags based on a document's appearance, content objects must be identified. As formatting is often a visual indicator of structure (headings are usually larger than surrounding text), but structure elements are relevant when formatting does not provide a cue.

All these elements of a given document type have to be arranged according to a hierarchical tree structure. For example we could represent a book containing a front and body part. The first of which contains a table of contents and the second chapter 1. Chapter 1 in turn contains Chapter 1.1 and a heading. Both instances can be derived from their ancestors (Contents and Chapter 1). Clearly, there are many such trees that might be drawn to describe document structure.

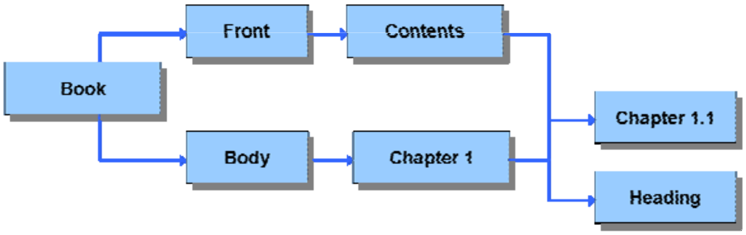


Figure 1: Document Tree - Inserting Structure Element Nodes into the XML-Tree

## 5. XML, DTD AND EXTENSIBLE STYLE LANGUAGE TRANSFORMATION

XML represents a consistent approach to identifying the document's components and how they relate to each other. The process permits explicit tagging to identify the components. Document structures can be defined depending on the specific requirements. XML also includes a DTD: Document Type Definition which defines the "allowed" elements and specifies the order in which the elements may or may not appear. The authoring process must produce documents that conform to the specifications of the DTD. Any document that is "valid" according to a specified DTD can be processed for the desired output and validated against the DTD by an XML parser - a check relating to the compliance with the DTD.

XML is a descriptive markup language rather than a procedural markup language. A descriptive markup language uses codes, called elements, to name and categorize parts of a document. It is designed to create documents where the computer processing the document can understand what the parts of the document are and assemble it appropriately. Procedural markup language, like that of HTML, is often used to represent text in a certain style like bold. <bold>This text is bold.</bold> allows a Web browser to represent the text as: **This text is bold.** XML-based documents may be transformed for Web, Braille, speech output, etc.

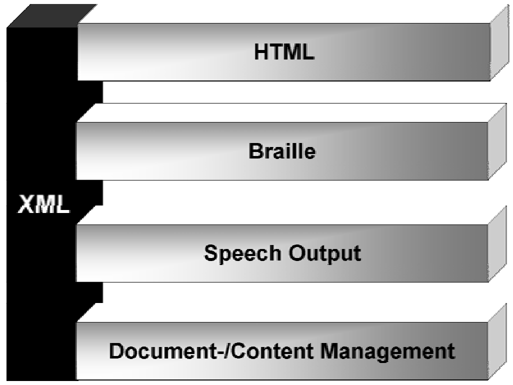


Figure 2: Transformation of XML-based Documents

The Extensible Stylesheet Language (XSL) describes how the XML document should be displayed. XSL-Transformation is used to transform an XML document into another type of document that is recognized by a browser, like HTML. Decisions about the handling and representation of each structure element into HTML can be taken, according to the needs of print disabled readers while elements and attributes can be added, removed, rearranged or hidden.

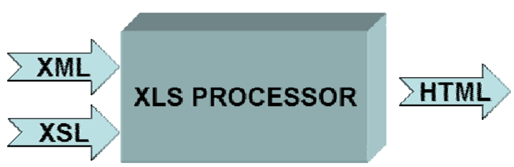


Figure 3: Process of Conversion

## 6. THE FIELD OF APPLICATION

With regard to selecting the relevant structure elements recognized as being of crucial importance for the accessible layout of books one established standard called "*Text Encoding Initiative*" has been referred to - "relevant" to the needs of print disabled readers. Building up on the TEI schema the accessible meta-data tagging specification is applied in the context of the authoring tool Adobe ® InDesign® CS. It supports the utilization of Document Type Definitions and therefore integrates XML files into its visually oriented publishing workflow consisting of the document's mark-up and the content. When applying the specification ensuring accessible documents, information providers were instructed to use the tools they have at hand.

The following examples show the relevance to accessibility:

***Example 1***

A text or other nonvisual description of a graphical element is intended to be an alternative to the graphical presentation:

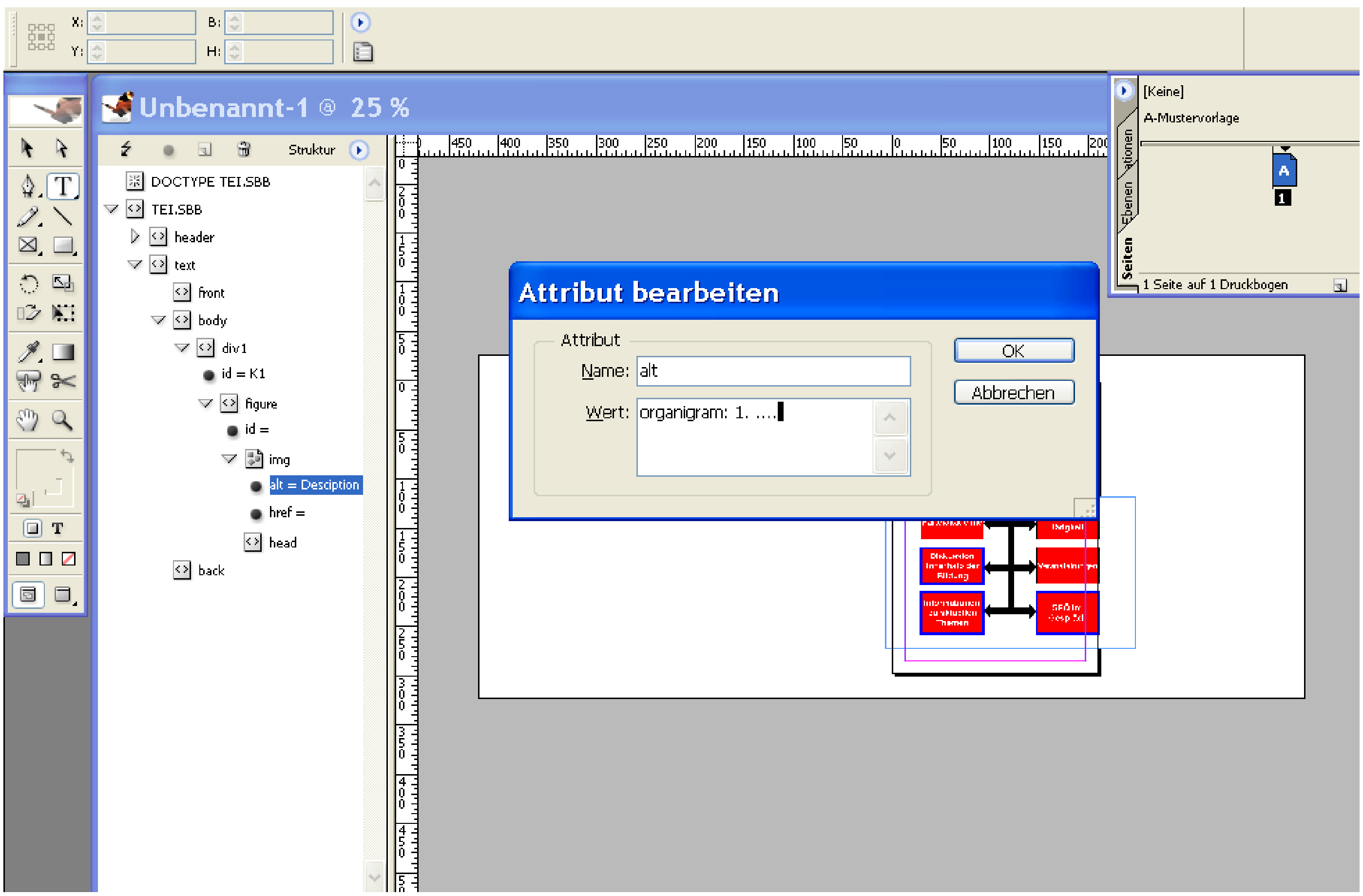


Figure 4: Applying an Alternative Description to a Figure with Adobe Indesign CS ®

***Example 2*** is an illustration of the necessity of structure for navigational purposes:

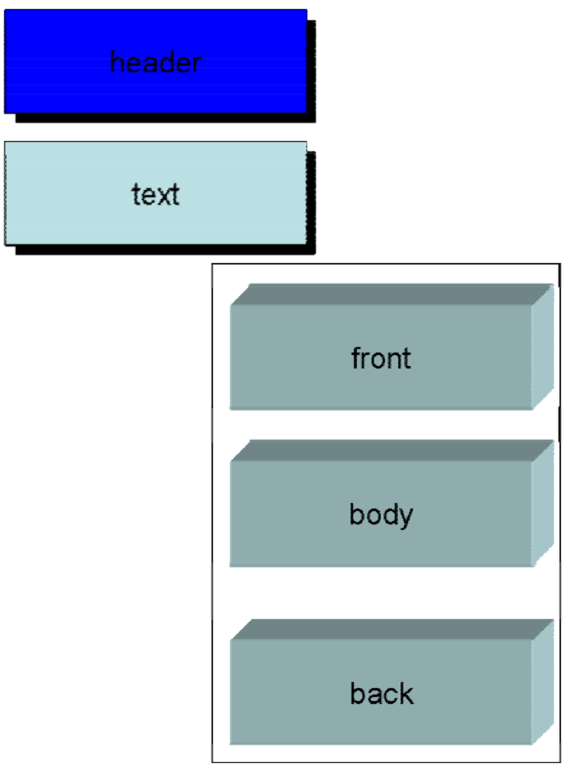
**ACCESSIBILITY OF TABLES**

W3C Techniques for Web Content Accessibility

**summary** information and identifying row and column information **row and column headers**

InDesign tables must conform to a specific structure and are rendered according to the CALS table model that refers to OASIS.

## 7. ARCHITECTURE OF THE DTD




The text body contains seven levels of hierarchy, representing the chapter structure. Within each level the following elements may be used as often as needed: Paragraph, Figure, Heading, List, Notes, References, Pagebreak, Linebreak, Pointer, Link, Style and Table.

Continuous text should be embedded in a paragraph whereas line breaks within a paragraph can be compelled by the use of an empty "lb" element. The page break as well is indicated by using the empty "pb" element and the page number of the next page is to be assigned as an attribute.

Individual table elements are tagged automatically by Adobe InDesign. The table-tag in the tag-set just acts as a container for the divers elements (e.g. <tr>...</tr>, <th>...</th>, <td>...</td> , <thead>...</thead>, <tbody>...</tbody>, <tfoot>...</tfoot>, ...).

Emph-tags create style elements by assigning of the following attributes: italic, bold, underline, overline or stroke.

The front is composed of the elements titlePage, contents, foreword, dedication, abstract, ack, docAuthor, docDate , docEdition, docImprint, docTitle and the back contains appendix, glossary, notes, bibliography, index and colophon.

## 8. CONCLUSIONS

Structured authoring offers the prospect of full access to learning materials for print disabled people who formerly were inhibited of being well educated. In a society where equitable access is being exercised the terms for normality and abnormality lose their meaning as characteristics of individuals!

## REFERENCES


TEI Consortium (2003). A Gentle Introduction to XML, XML Version of the TEI Guidelines, Text Encoding Initiative, www.tei-c.org.

Cullen, R. (2001). *Addressing the Digital Divide,* School of Information Management, Victoria University of Wellington.

Adobe ® InDesign® CS. (Screenshots)

University of Wisconsin – Stout (2001). Information from the W3C Techniques for Web Content Accessibility Guidelines 1.0,www.uwstout.edu/solutions/lts/webid/tutorials/accessibility.htm.

Scriptorium Publishing Services, Inc. (2002). Structured Authoring and XML.

Paille, Norman, Klassen, Maxwell (1999). The Effect of Using Structured Documents (SGML) in Instructional Design.

Workshop on Advanced Learning Technologies for Disabled and Non-Disabled People (WALTD)
at
**The 7th IEEE International Conference on Advanced Learning Technologies (ICALT 2007) July 18-20, 2007, Niigata, Japan**

http://www.icaltd.doc.gold.ac.uk/

# A User-Centred Approach for Developing and Evaluating Advanced Learning Technologies Based on the Comprehensive Assistive Technology Model

**Marion A. Hersh[(1)] and Michael A. Johnson[(2)]**

[(1)] Dept. of Electronics and Electrical Engineering,
University of Glasgow, Glasgow, G12 8LT, U.K.

[(2)] Dept. of Electronic and Electrical Engineering,
University of Strathclyde, Glasgow, G1 1QE, U.K.

**Abstract:** Learning technologies are becoming increasingly important in education. Many disabled people experience barriers in accessing education and therefore these learning technologies need to facilitate access to education for disabled people rather than generate additional barriers. There is therefore a need for development and evaluation methodologies for advanced learning technologies which take account of the needs of disabled people.

The main aims of this paper are the presentation of a user-centred design approach for (advanced) learning technologies and its link to the Comprehensive Assistive Technology (CAT) model developed by the authors and a user-centred evaluation methodology for learning technologies based on the CAT model. The application of this methodology is then illustrated by its application to a calculator for dyslexic children.

Keywords, learning technologies, dyslexia, dyscalculia, accessibility and usability, design and evaluation, assistive technology modelling.

## 1. Introduction

Education should be considered a basic right, but many disabled people experience numerous barriers in accessing it. A wide range of learning technologies, including computer-based ones, are becoming increasingly important in educational practice. It is therefore important that these technologies are fully accessible to disabled people.

Although disabled people often experience serious barriers in accessing and getting the greatest benefits from education, there have been advances and there are examples of good practice. In some cases there may be benefits, such as avoiding unnecessary complexity or including features only required by a specific group or groups of learners in designing learning technologies for a particular group of disabled people. However, there are clearly advantages in extending the intended group of users by taking the needs of several different groups of learners into account in the design process or, where possible, using a design for all approach.

There is also a need for tools that can support both the design process for new learning technologies and evaluate existing technologies. The paper has the following two aims:

- The presentation of a user-centred design approach for (advanced) learning technologies and its links to the Comprehensive Assistive Technology (CAT) model derived by the authors (Hersh and Johnson, 2006, 2007).
- A user-centred evaluation methodology for learning technologies based on the CAT model.

The application of the evaluation methodology is illustrated by the example of a multi-media calculator for primary school students with dyslexia.

The paper is organised as follows: Section 2 contains a brief introduction to the CAT model. Section 3 briefly discusses the specific learning disabilities of dyscalculia and dyslexia and presents the idea of a pedagogy of diversity. Sections 4 and 5 contain the main contributions of the paper in terms of an iterative approach based on the CAT model for developing learning technologies, a methodology based on the CAT model for evaluating learning technologies and an example of its application to the development of a calculator for children with specific learning disabilities. Conclusions are presented in section 6.

## 2 The CAT Model

The CAT model (Hersh and Johnson, 2006, 2007) gives a comprehensive description of an assistive or other technology system in terms of the characteristics of the person using it, the activities they are carrying out, the technical, end-user and other specifications of the technology and the context in which the technology is being used. The model has a number of different applications, including the analysis of existing (assistive) technologies and drawing up specifications for new technologies. The model has a hierarchical structure from the top level components of person, context, technology and activity, which can be described as follows:

The main components of the person section of the model are:

- Social aspects: community support; education and employment.
- Attitudes: attitude towards technology; general attitudes.
- Characteristics: personal information; impairments; skills; preferences.

The main components of the context component of the model are:

- Social and cultural context: wider social and cultural context; user's social and cultural context.
- National context: infrastructure; legislation; assistive or other technology context
- Local settings: location and environment; physical variables.

The assistive technology system component of the model is as follows:

- Activity specification: task specifications; user requirements.
- Design issues: design approach; technology selection.
- System technology issues: system interface; technical performance.
- End user issues: ease and attractiveness of use; mode of use; training requirements; documentation.

The activities component of the model is as follows:

- Mobility: reaching and lifting; sitting and standing; short distance locomotion inside and outside; movement on ramps, slopes, stairs and hills; obstacle avoidance; navigation and orientation; access to environment.
- Communications and access to information: interpersonal communication; access to print media; telecommunications; computers and internet; communications using other technologies.
- Cognitive activities: analysing information; logical creative and imaginative thinking; planning and organising; decision making; categorising; calculating; experiencing and expressing emotions.
- Daily living: personal care; timekeeping, alarms and alerting; food preparation and consumption; environmental control and household appliances; money, finance and shopping; sexual and reproductive activities.
- Education and employment: learning and teaching; professional and person-centres; scientific and technical; administrative and secretarial; skilled and non-skilled trades; outdoor working.
- Recreational activities: access to the visual, audio and performing arts; games, puzzles, toys and collecting; holidays and visits – museums and galleries; sports and outdoor activities; DIY, art and craft activities; friendships and relationships.

## 3. Learning Disabilities in Mathematics

Learning disabilities can be divided into the two main classes of specific and general learning disabilities. The two main types of specific learning disabilities are dyscalculia or mathematics learning disabilities and dyslexia or literacy learning disabilities. A sizeable group of people with dyscalculia also have dyslexia.

An estimated 5-8% of school-age children have specific learning disabilities in one or more areas of mathematics (Geary, 2004). Empirical studies have found that children with specific learning difficulties in mathematics often use strategies which do not require mental retrieval of number facts (Gersten et al., 2005). This supports the theory that they have poor short term memory retrieval skills (Dowker, 2005). There is also empirical evidence that one of the main distinguishing features of children with dyscalculia is difficulties with multistep arithmetic (Bryant et al., 2000). Since the term mathematics encompasses diverse topics which make different cognitive demands, specific learning disabilities may impact on some areas of mathematics, but not others (Geary, 2004). However most research in the area has concentrated on arithmetic and number skills.

A relatively small number of both computer-based and other tools have been developed to support people with (specific) learning difficulties. However most of the commercially or freely available tools focus on children, rather than adults or the full age range. A study of the literature indicates that coverage of mathematics topics is also relatively limited and generally related to basic numeracy skills rather than more advanced topics and concepts. There is therefore a need for further research on tools, methodologies and learning approaches to support mathematical and numeracy learning by people with dyscalculia of all ages and stages of education. There are also questions as to the role of (computer) technology in this process, whether and in what circumstances it can be an enabler rather than a further hurdle to be overcome and the appropriate balance between computer based resources and other types of support.

### 3.1 Pedagogy of Diversity

There is evidence that people with specific learning disabilities have particular cognitive approaches which are different from those of the non-learning disabled population. They therefore need learning approaches and technologies which are compatible with their cognitive styles. This gives rise to a need for a pedagogy of diversity, based on appropriate learning methodologies and approaches for the full diversity of students and which enables all students to draw on their strengths. This pedagogy would need to include consideration of the following factors (Hersh and Stapleton, 2006):

- The essential learning goals of the particular educational programme. Often an educational programme may have a number of goals which are not really essential and which have developed for historical or other reasons. Removing these goals may make the programme accessible to disabled people.
- The involvement of students in course design and flexible, creative approaches, which take account of the needs, circumstances and context of all students, rather than rigidly applied principles.
- Learning approaches which encourage students to meet the learning objectives while taking into account different learning styles, and a range of resources, with support to help students choose the most appropriate approaches and resources. This should enable all students to draw on their strengths and to use these strengths to support the areas in which they have weaknesses (Price, 2006). All these different resources and approaches should be available to all students. This is particularly important for students with specific learning disabilities.
- Access to the same types of experience, such as field trips and laboratory work, and the social aspects of education, including the need for peer acceptance. In some cases this will mean modifying the basic approach to make it accessible to all students. Alternatively different groups of students could undertake one of a number of options, such as different field trips, and share their experiences afterwards.
- Challenging and stretching all students to the optimal extent for the particular student, without making any student feel overwhelmed or stressed.
- Provision of assignment measures and methodologies which are fair to all students.

- Provision of sufficient resources by the institution, including teaching materials and staff time (academic, technician, secretarial, administrative and other) to prepare the different approaches and resources. This is unfortunately counter to current trends in countries such as the UK, where the staff: student ratio has increased from 1:9 in the mid-1970s to nearly 1:21 in 2003-4 and is expected to increase to 1:23 by 2010 (AUT, undated, 2002).

### 3.2 Accessibility and Usability

In the context of technology for disabled people there has been a tendency to focus on accessibility, for instance, of computer system or web pages. Accessibility is about the environmental characteristics of the system input and output which either enable or prevent particular groups of users from using the system. It can be defined in terms of the absence of barriers to carrying out a particular activity and the presence of factors, which may be structural or psychological, which facilitate carrying out this activity.

However, usability or the extent to which a particular group of users can use a particular system in their particular context to achieve specified goals effectively, efficiently and with satisfaction (Federici et al., 2005; ISO, 1998) is equally important. It has been characterised in terms of the following six components (McLaughlin and Skinner, 2000): allowing checks that the correct information is entering and leaving the system; user confidence in both the system and their ability to use it; user control over system operations, including input and output information; ease of use; fast response; user understanding of the system and its outputs. Therefore usability depends on design features and user characteristics, as well as the context in which it is intended to use the system.

In the context of learning technologies, there are two types of accessibility and usability issues:
- Accessibility and usability of the learning technology itself.
- The use of the learning technology to overcome accessibility barriers that would otherwise affect the learning process, for instance due to a mismatch between the cognitive approaches used by the learner and assumed by the teacher or the presentation of material in a visual format to blind learners.

## 4. A Framework for Developing and Evaluating Advanced Learning Technologies Based on the CAT Model

This section presents a user-centred design approach for (advanced) learning technologies and its links to the CAT model and a user-centred evaluation methodology for learning technologies based on the CAT model.

### 4.1 Methodology for Developing Advanced Learning Technologies

The CAT modelling approach can be used to derive a structured and user-centred approach to developing advanced learning technologies. It should be noted that some of the factors discussed in the steps may not always be relevant. The approach presented below is iterative and some steps or sequences of steps may be repeated many times.
1. Determination of the learning activity or activities to be supported by the technology. The activity section of the CAT model can be used to define some of the activities involved. This leads to detailing the task specifications in the activity specification section of the assistive technology system component of the model.
2. Determination of the user requirements in the activity specification section of the assistive technology system component of the model. These requirements can be obtained by referring to the person section of the model and in particular the user characteristics and attitudes. Advanced learning technologies are occasionally designed for a specific end-user, but more likely to be designed for a particular group of end-users. Therefore the personal information will be generic, for instance the age group and whether male or female or mixed gender. In some cases a design for all approach is most appropriate. In others it is useful to have a design which takes account of the specific needs of particular groups of disabled people. This will affect factors such as the system interface, so that disabled users can interact with the technology, the

underlying cognitive approaches and the language or symbols used, including in documentation, so that they are comprehensible. The group may be homogenous with regards to skills or there may be significant variation with regards to possession of the relevant skills across the group of learners. There is generally a relationship between skills and education and employment. Preferences of relevance include factors such as appearance and degree of customisability. It is often useful or even essential to evaluate the skills and preferences of the intended user group by carrying out a survey of a representative sample. The education and employment and skill profile of the user group will determine the types of functionality the learners require, for instance basic or more advanced principles and techniques.

3. Determination of the context in which the advanced learning technology will be used. This will influence many of the design specifications. The wider and user's social and cultural contexts will determine the appropriate language for text or speech output, menus and documentation. It will also determine the way particular words or symbols are likely to be understood and any words or symbols that should be avoided in order not to cause offence. The infrastructure component of the national context and the location, environment and physical variables can put constraints on what is appropriate in terms of the design. In particular, it may be necessary to design any hardware to be robust to humidity or extreme temperatures. The infrastructure for maintaining, repairing and updating the technology locally also has to be considered to avoid it being abandoned the first time a problem occurs. Computer based learning technologies will generally be inappropriate for areas with an intermittent electricity supply, unless a locally appropriate solution to the computer power requirements can be obtained. The existence of legislation on the rights of disabled people could contribute to overcoming any barriers to the technology getting to disabled learners.
4. Design specification: this includes the design and system technology issues sections of the assistive technology system component of the model, leading to selection of the design approach, the technical performance requirements, the technology and the system interface. Selection of the system interface will be largely determined by the end-user characteristics already considered.
5. Evaluation of the design in terms of end-user issues, including ease and attractiveness of use and mode of use. This will require consideration of both the end-user characteristics and the context of use.
6. Documentation and training: This will include consideration of the end user characteristics, as these will determine a number of important features of the documentation, including format(s) e.g. as text on paper, as an audio CD, in Braille or as a video or DVD; the type of language and symbols used; and the level at which the information is pitched e.g. for experienced or novice users of the technology. Both the local and wider social and cultural contexts need to be taken into account in determining the appropriate language and symbols for documentation. Information about the education and employment profile and likely skills of the end-user group can often be used to determine whether they should be classified as novice or experienced users and their requirements for documentation. The support component of the social aspects feature of the person section of the model should be taken into account in determining the requirements for documentation and training. This includes consideration of the support available to the user from the community and/or family and friends. This should include whether training should also be developed for others in addition to the direct end-user.
7. Construction of the device.
8. Cycle of end-user testing and repeated modifications. This will include evaluation in terms of the assistive technology system components of the model, including:
   - End-user satisfaction with the ease and attractiveness of use, mode of operation, system interface, training provision and documentation.
   - Functionality, including carrying out the required tasks, technical performance and performance of the interface.
   - Overall design.

### 4.2 Methodology for Evaluating Advanced Learning Technologies

The CAT model can be applied to the evaluation of advanced learning technologies by matching or comparing the different features of the particular technology with the associated requirements of the person, context and assistive technology modules of the model. The accessibility and usability with which the technology achieves the required learning outcomes can also be assessed using the requirements for accessibility and usability discussed in section 3.2 above and evaluating them for the particular user group, context and technology. As in the case of the methodology for developing advanced learning technologies, not all features of the evaluation process will be relevant. In particular some of the factors, such as robustness to local environmental conditions, including temperature extremes, will be only relevant to hardware, whereas many learning technologies are in the form of software. The evaluation procedure will now be set out in the form of a series of questions relating to each component of the model.

**Person**: Is the learning technology appropriate for the intended group(s) of users?

*Characteristics*: Is the technology age-appropriate? What basic, intermediate and advanced skills are learners required to have? Is this realistic for the intended group of learners? Has the technology taken into account learners' impairments, for instance in the choice of appropriate means of inputting and outputting information and the use of symbols and language. Have learner preferences been considered, for instance with regards to the appearance of any hardware and the mode and format of provision of information?

*Attitudes*: Is the technology appropriate in terms of what is known about the intended learners attitudes' to learning and the use of learning technologies?

*Social aspects*: What is the likely education and employment profile of the group of learners? Is this appropriate to the technology in terms of the knowledge, understanding and experience required? What support or encouragement to learning in general and using the specific advanced learning technology, in particular, is likely to be available to the particular group of learners from family and friends, teachers/tutors or the wider community? Is this support sufficient for learners to have a positive experience of using the technology?

**Context**: Is the learning technology appropriate to the context in which it will be used?

*Social and cultural*: Are any examples, symbols, metaphors, graphics and stories culturally appropriate and comprehensible? Have any sources of ambiguity or possible offensiveness been avoided? Is the language used one the users are fluent in?

*National infrastructure*: Is the available infrastructure able to support the technology? Have any unrealistic assumptions been made e.g. availability of technicians, continuous electricity supply? Is it possible to maintain, repair and update the technology locally?

*Local settings*: Can the technology function under the local conditions? Is it robust enough to cope with any extremes of temperature or humidity? Is it robust enough to cope with being dropped, getting wet and less than careful handling, particularly if the intended learners are children? Is the format of the system outputs and inputs appropriate to the local physical variables as well as the learners? For instance, will the environment be quiet enough for the learners to hear any speech or other audio output? Have headphones been provided so that audio output will not disturb other learners? Is there sufficient illumination to see a screen or keyboard clearly, particularly if some of the learners have low vision? What type of learning setting is the technology intended to be used in? A class-room? The learner's own home? A computer laboratory? Does this setting put any constraints on the design? Have these constraints been taken into account? What type of technology is likely to be familiar to learners in the local context? Is the learning technology of a type that will fit easily into this context?

*Legislation*: Does the learning technology comply with all relevant local, national and international regulations? Has any use been made of legislation that promotes learning technology in general or specifically for disabled people in particular?

**Assistive technology system, accessibility and usability**: Does the learning technology support learners to carry out the intended learning activities and is it fully accessible and usable by them?

*Activity specification*: What are the user requirements? How have they been taken into account? How has the target learner community been involved in the design process? Does the advanced learning technology meet learner needs? Have the tasks to be carried out been sufficiently precisely specified? Are there any accessibility barriers? Do the learners have control over the system operations, including input and output information?

*Design issues*: Has the design approach taken account of learner requirements and task specifications? What were the different technology options? What criteria were used in selecting the technologies chosen? How have these choices affected the performance of the learning technology and end-user satisfaction?

*System technology issues*: What is the system interface? Does it allow all learners to access input and output information? Does it present any accessibility or other barriers to the intended learner community? Does the system interface allow user control over system operations, including input and output information? What criteria are being used to judge technical performance? Is performance satisfactory in terms of these criteria? Does the interface allow checks that correct information is entering and leaving the system? Are these checks provided in an appropriate format? Is the system customisable e.g. the length of time users are given to respond to prompts and whether and in what format checks are provided?

*End user issues*: Have end-user tests been carried out? Has both qualitative and quantitative information on system performance been obtained? How easy is the system to use? How enjoyable is it to use? Are there any features that the desired group of learners may find off-putting or which may act as barriers? Is the mode of use appropriate for this group? What training is required by the particular group of learners? What, if any, training is available? Is it sufficient and appropriate? Are there any accessibility or other barriers which would prevent learners accessing this training? Is any training required by teachers, tutors, family members, friends, professionals or other people? Is this training being provided in appropriate forms? Are there any accessibility barriers to this training? What documentation is required? What documentation is provided? Is documentation provided in appropriate formats for the group of learners e.g. audio on tape or CD, electronic form to be used with screenreaders and Braille for blind learners. Is the language used in the documentation fluently understood by the group of learners? Is the level of language appropriate to them? Are any symbols, graphics and examples culturally appropriate and easily understood by the group of learners?

## 5. Example of the Application of the Approach to Designing a Calculator for Children with Specific Learning Disabilities

The evaluation methodology presented in section 4 will be illustrated by the example of an on-screen calculator developed by Orton-Flynn and Richards (2000) using multimedia tools for children with specific learning difficulties, in this case dyslexia. This section presents the results of applying this methodology under the three main headings of Person; Context; and Assistive technology system, accessibility and usability.

**Person**

*Characteristics:* The calculator has been designed for primary school students, both girls and boys, particularly those with dyslexia. However, there are advantages in it being useable by all primary school students, including those with other impairments and those who are good at mathematics. The design is age appropriate. The skills required are the ability to select a key from the on-screen keypad using a mouse or assistive device, such as a switch, the ability to choose the correct key and to read a simple display with clear fonts, supported by audio feedback, to use interactive base ten blocks, to recognise and use the four arithmetic symbols and the 10 digits and to work out by hand and to estimate the answers to simple calculations. Some of these skills, such as working out and estimating the answers to simple calculations and recognising the four arithmetic symbols, are skills the users are learning and where learning is being supported or reinforced by the use of the calculator. Some modifications, such as the ability to access the on-screen keypad from the keyboard in addition to the mouse would be required to make the calculator useable by blind children. The use of colour is likely to be helpful to most users. However, some users find on-screen colour difficult to look at and therefore an option to customise it out would be useful. The fact that the main user group has dyslexia has been taken into account in a number of ways. This includes the presentation of answers in spoken as well as visual form, the use of a very clear font and the organisation of the keypad with ‘1’, ‘2’, ‘3’ rather than ‘7’, ‘8’, ‘9’ on the top row, as this is a more natural organisation.

The appearance of the hardware and display are likely to be attractive to most users in this age group.

*Attitudes*: Many school children are nervous about numbers and calculation and many of them have already had bad experiences. The calculator is designed to increase their confidence. School children generally have a positive attitude to the use of learning technologies, particularly when they are multi-media or computer based.

*Social Aspects*: The group of learners are all primary school students. There are no requirements for knowledge, understanding and experience and the only requirements are the skills listed above. The support available, particularly from family and friends, will depend on a number of different factors, including the individual child's circumstances. Therefore, support from teachers and class room assistants is particularly important. The practical support that they can provide will depend on a number of factors, including their attitudes to dyslexia and class sizes. It is generally easier to provide support in smaller classes. There is increasing recognition that dyslexia is a 'real' disability, but this is still by no means universal and the degree of recognition varies considerably between countries. In the UK a high proportion of teachers consider that calculators are an essential tool in the primary school classroom, but that it is important that pupils understand the principles of arithmetic and are able to independently validate the answers given by the calculator (Orton-Flynn and Richards, 2000). Since the multi-media calculator supports learning the principles of arithmetic and acquiring the ability to validate answers, teachers are likely to be supportive of its use. However, they may require information on what it is able to do. There is very little information available about dyslexia in the countries with low literacy, but there is likely to be very little if any support available.

**Context**

*Social and cultural*: The calculator has been developed specifically for children with dyslexia and therefore the use of complex language has been avoided. The symbols used are the standard mathematical ones. The calculator has been developed in UK English and is therefore useful for children in the UK. Since the expressions used are simple, the calculator can probably be used in other English speaking countries. Since dyslexia is not restricted to the UK, the development of the calculator in other languages would be useful. There is increasing official recognition of the importance of educating disabled children in mainstream schools, as demanded by organisations of disabled people, such as Inclusion Scotland. This will require adequate resources and the provision of appropriate learning technologies such as the multi-media calculator.

*National Infrastructure*: The infrastructure in the UK is suitable to support the calculator and to maintain and update both the calculator software and the associated computer soft and hardware. No unrealistic assumptions have been made. The same is true of other English speaking countries, such as the USA and Australia. However, there are likely to be infrastructure issues, such as the lack of availability of computers and intermittent electricity supplies, in some of the poorer countries.

*Local settings*: Robustness to local conditions relates to the computer hardware, not the calculator software. This is not an issue in most countries, but may become an issue if a handheld version is developed. Since the calculator has speech output, it should be used with headphones in a classroom, computer laboratory or library setting to avoid disturbance to other school students or library users and enable several students to use the calculator at the same time. Headphone use will also make it easier for the students to receive the speech output if the classroom is noisy. This issue is not discussed by the developers. There should be sufficient illumination in a class room, library or computer laboratory for the use of the calculator, but there may not be if the calculator is used at home. The calculator seems largely intended to be used in a classroom or other school based learning space. However students may want to use it at home as well. The calculator software uses a computer to provide access to an on-screen calculator. The underlying computer technology will be reasonably familiar to primary school students in the UK and most of the industrialised countries, but unfamiliar to students outside these countries.

*Legislation*: There is a range of legislation and regulations which should be met by the computer on which the calculator software is used. However, this is not specifically relevant to the calculator. A number of countries have legislation on the rights of disabled people, including access to education, for instance Section IV of the Disability Discrimination Act 1995 in the UK, introduced as the Special Educational Needs and Disability Act 2001 (http://www.legislation.hmso.gov.uk/acts/acts2001). The

5-14 National Curriculum in England and Wales (http://www.qca.org.uk/232.html) made the use of calculators in the classroom mandatory. The Scottish 5-14 Mathematics Curriculum (http://www.ltscotland.org.uk/5to14/) recognises the need to teach specific calculator skills, such as reading and interpreting displays, as well as the ability to approximate and estimate. These are all skills that are supported by the multi-media calculator.

**Assistive technology system, accessibility and usability**

*Activity specification*: The activities comprise calculations involving the four operations of addition, subtraction, multiplication and division, accessing the multiplication tables, using interactive base ten blocks to work out calculations, estimating the answer to a problem and checking the result. User requirements include a system which is easy and intuitive to operate and which motivates primary school students to learn. Specific requirements include customisable audio and visual feedback of all steps in the computation, an easy to use on-screen keypad layout with easily recognisable keys and numerical digits and colour coding or other means of distinguishing digits and operation keys from each other, as well as the ability to save and print out calculations. Although the calculator is targeted specifically at students with dyslexia, it should be useable by all primary school students, including those who are gifted at mathematics. This may require additional functionality for children who find mathematics easy.

*Design issues*: The design approach was based on a top-down-structure for the calculator with investigations for some of the interface components. Classroom observations of performance with a sample of targeted endusers led to a cycle of iterative refinements to the overall design. The criteria used in retaining or removing features were ease of use and usefulness to users. Multimedia authoring tools were a key feature of the development process. The use of these tools allowed constant updating of the working prototype in response to classroom observations and new user requirements. A need for colourful graphics and audio facilities was recognised.

*System technology issues*: The multi-media calculator is currently available via CD to be used on a PC or macintosh computer. The developers recognise that there would be value in developing a handheld version, but that the costs of small colour LCD displays are currently too high. One approach to a handheld version would be through a personal data assistant (PDA) or palmtop computer, but the size of the display may be too small. The CD and on-screen buttons are accessed via a mouse, but an assistive device, such as a switch could be used. Consultation with usability research (Deininger, 1960; Conrad and Hull, 1968) was used to choose a keypad layout with '1', '2', '3' rather than '7', '8', '9' on the top row. The font was specially designed (Orton-Flynn and Richards, 2000) to be easy to read and avoid confusion between symbols or between digits. Both audio and visual feedback are given for each action and there is the option of saving and/or printing out calculations. There is only limited ability to customise the calculator, by the teacher. Further customisation, for instance, to change or remove colours would be useful, as well as a very simple customisation that could be carried out by students themselves.

*System technology issues*

*End user issues*: End-user testing, involving quantitative and qualitative evaluation and evaluation of use of the calculator in the class room, has been carried out. Feedback from the evaluation has been used to modify the calculator design: features that were easy to use or useful were retained and other features were discarded. Further evaluation with primary school students may be required, but evaluation to date has shown the calculator to be easy and attractive to use. Simple documentation of the calculators' features could easily be provided on the interactive CD on which the calculator software is made available. This should provide sufficient information to allow teachers to use the calculator themselves and to instruct school children in its use. The documentation would need to be set up appropriately to enable it to be accessed by screen readers, if required. The CD can be accessed using a mouse or tracker ball, as well as switches or other assistive devices.

This evaluation of the multi-media calculator has demonstrated that it is appropriate to the intended user group and in the context of the UK and some other English-speaking countries, such as the USA and Australia. It has also identified features not considered by the original developers, such as the requirement for headphones and the need for a greater degree of customisability and access to the on-screen keypad via the computer keyboard for the calculator to be accessible to students with additional impairments. The evaluation methodology has also been able to identify issues to be considered if the calculator is to be used outside the UK.

The example has also illustrated the value of the evaluation methodology based on the CAT model. The methodology is able to identify and evaluate the main features of an advanced learning technology. In particular, it is able to identify issues that have not been considered by the technology authors.

## 6. Conclusions

The paper has illustrated the application of the Comprehensive Assistive Technology (CAT) model developed by the authors (Hersh and Johnson, 2007) in the development and evaluation of (advanced) learning technologies. An approach for developing learning technologies linked to the CAT model and an evaluation methodology directly based on the CAT model were presented. The evaluation methodology was illustrated by application to a multi-media calculator for primary school students with dyslexia. The development of the methodologies was set in the context of the need for a pedagogy of diversity and the importance of taking account of accessibility and usability factors in all technology development.

## References


AUT (undated), *Staff-Student Ratios*, http://www.aut.org.uk/index.cfm/media/pdf/c/3/media/pdf/index.cfm?articleid=133

AUT (2002), *Nation's Universities in Crisis, says AUT*, http://www.aut.org.uk/index.cfm/media/pdf/c/3/media/pdf/index.cfm?articleid=290

Bryant, D., B.R. Bryant and D.D. Hammill (2000). Characteristic behaviors of students with learning disabilities who have teacher-defined math weakness. *J. Learning Disabilities*, vol. 33, pp. 168-179.

Conrad, R. and A.J. Hull (1968). The preferred layout for numeral data entry keysets. *J. Ergonomics*, vol. 11(2), pp. 354-356.

Deininger, R.L. (1960). Desirable push-both characteristics. *IRE Trans on Human Factors in Electronics*, March, pp. 24-30.

Dowker, A. (2005). Early identification and intervention for students with mathematics difficulties, *J. Learning Disabilities*, vol. 38(4), pp. 324-332.

Federici, S. et al. (2005). Checking an integrated model of web accessibility and usability evaluation for disabled people, *Disability and Rehabilitation*, vol. 27(13), pp. 781-790.

Geary, D.C. (2004). Mathematics and learning disabilities. *J. Learning Disabilities*, vol. 37(1), pp. 4-15.

Gersten, R., N.C. Jordan and Flojo (2005). Early identification and intervention for students with mathematics difficulties, *J. of Learning Disabilities*, vol. 38(4), pp. 293-204.

Hersh, M.A., and M.A. Johnson (2006), On modelling assistive technology systems, Procs. Conference on Assistive Technology for Vision and Hearing Impaired People, 18-21 July, 2006, Kufstein, Austria.

Hersh, M.A. and Johnson, M.A., (2007.) Disability and assistive technology systems, In: Hersh, M.A. and M.A. Johnson (Editors), *Assistive Technology for Visually Impaired and Blind People* (In Press), 978-1-84628-866-1, Springer Verlag London Ltd., Guildford, U.K.

Hersh, M.A. and L. Stapleton (2006). LearnMaths: A case study of the development of learning software to support social inclusion, ISA '06, Prishtina, Kosovo.

ISO, (1998). *Ergonomic Requirements for Office Work with Visual Display Terminals (VDTs) Part 11: Guidance on Usability 9241-11,* International Organization for Standardization.

McLaughlin, J. and D. Skinner (2000). Developing usability and utility: a comparative study of the users of new IT, *Technology Analysis and Strategic Management*, vol. 12(3), pp. 413-423.

Orton-Flynn, S. and C.J. Richards, The design and evaluation of an interactive calculator for children, Digital Creativity, vol. 11(4), pp. 205-217.

Price, G.A. (2006). Creative solutions to making the technology work: three case studies of dyslexic writers in higher education, *Research in Learning Technology*, vol. *14(1),* pp. 21-38.