Revealing the whiteboard to blind students: An inclusive approach to provide mediation in synchronous e-learning activities

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Abstract

Promoting the inclusion of students with disabilities in e-learning systems has brought many challenges for researchers and educators. The use of synchronous communication tools such as interactive whiteboards has been regarded as an obstacle for inclusive education. In this paper, we present the proposal of an inclusive approach to provide blind students with the possibility to participate in live learning sessions with whiteboard software. The approach is based on the provision of accessible textual descriptions by a live mediator. With the accessible descriptions, students are able to navigate through the elements and explore the content of the class using screen readers. The method used for this study consisted of the implementation of a software prototype within a virtual learning environment and a case study with the participation of a blind student in a live distance class. The results from the case study have shown that this approach can be very effective, and may be a starting point to provide blind students with resources they had previously been deprived from. The proof of concept implemented has shown that many further possibilities may be explored to enhance the interaction of blind users with educational content in whiteboards, and further pedagogical approaches can be investigated from this proposal.

1. Introduction

The use of e-learning and other technologies has brought an increasingly higher number of possibilities to augment educational resources. New technologies such as video-conference, interactive whiteboards and others have empowered the possibilities for more interaction in learning environments.

Particularly, the use of interactive whiteboards (IWBs) in educational contexts has been reported by a number of research works (Gillen, Staarmann, Littleton, Mercer, & Twiner, 2007; Glover, Miller, Avers, & Door, 2007; Kennewell & Beauchamp, 2007; Mohon, 2008; Schmid, 2008; Warwick & Kershner, 2008). Interactive whiteboards provide very interesting features to promote synchronous interaction between students, teachers and other people involved in the learning process. The use of pen-based interaction may make the interaction easier and more natural, in a way that the content drawn on the board can be captured and accessed later. Besides, the use of IWBs with network devices also allows for the possibility of students, teachers and other participants to collaborate on the creation of content.

However, the use of rich multimedia based applications and of different interaction methods has brought a number of challenges regarding accessibility issues in e-learning systems. Whilst the use of such features may improve much of the learning experience for many students, it may become a barrier for students with disabilities, should proper adaptations not be taken.

In the particular case of the systems that use IWBs, providing inclusive means to enable students with different disabilities to use them remains a great challenge. Although we could find reports on systems that may enable students with motor disabilities to use interactive whiteboards (Acomm, 2009), the intrinsically graphical nature of such systems seems to be still a significant barrier for its use by blind students.

In this paper we present an approach to promote inclusive access to IWB systems to blind students. The approach is based on the use of features to provide mediation for these students, in a model similar to those used by sign language interpreters for deaf students. The mediation consists of the inclusion of accessible textual descriptions for graphical objects synchronously during a live learning session. This approach also enables students to directly interact with textual descriptions, by means of spacial navigation through the elements drawn on the board.

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The proposed approach was implemented by means of a prototype based on an existing implementation of an IWB software used in a well known virtual learning environment. The implementation of the prototype was followed by a case study with a blind student using the IWB software in a distant learning scenario. The results from a qualitative analysis of a usability evaluation and of an interview are presented.

This paper is organized as follows. Section 2 presents essential concepts regarding e-learning and inclusive education. Section 3 discusses the main features of our proposal for mediation in IWB software products. Section 4 presents the main issues related to the prototype implemented as proof of concept for this approach. Section 6 highlights the planning and execution of the case study with the use of the prototype. Section 7 presents the main results and discussions from the development of the prototype and from the case study and, finally, Section 8 discusses the main conclusions and future work.

2. E-learning and inclusive education

The use of computer-based systems to support educational activities has been a long-term field of research. It has been recognized that the use of such systems has a big potential to improve the development of the activities in educational environments.

The development of virtual learning environments has boosted a number of opportunities for both distance and co-located learning scenarios. These systems normally work over the Internet to support teaching and learning. They have been widely used in many educational institutions to provide a framework for many courses. Much of the communication between students, teachers and other people involved in the learning process is done by means of tools available in virtual learning environments.

Eibl and Schubert (2008) (chap. 30) have pointed out a set of important attributes that should be observed in the design of an e-learning system:

- Equal opportunities.
- Social support by co-operation and communication.
- Activities of students as important steps of the learning process.
- Priority to meet learning objectives.
- Flexible learning.
- Integration of e-learning in the learning environment.

As the use of virtual learning environments and other computer-based educational resources increases each day, the concern about how to provide inclusion for every student in these systems is crucial. If the educational tools are not developed properly, the use of such systems may become an additional factor to make students with disabilities excluded from the learning process.

Even though, it is important to consider the way in which the use of computers has boosted a lot of opportunities to everyone to make their lives easier. The development of assistive technologies has provided people with disabilities with amazing opportunities to make their day-to-day lives more productive.

For the particular case of people with visual impairments, such as blind people, the use of assistive technologies is crucial to give them more autonomy to perform their routine tasks using the computer. The main assistive technology used by blind people is the screen reader. A screen reader is a software that “reads” the content displayed in the screen by means of a speech synthesizer. With a screen reader, a blind user is able to interact with computer applications using the keyboard and to listen to the output via voice.

The development of such assistive technologies still presents many challenges to overcome. Many common activities carried out with a computer are still surrounded by barriers for people with different disabilities (Hull, 2004).

Although many advances on assistive technologies have recently emerged, a number of issues inherent to the means used for interaction in usual technologies arise. For example, graphical resources in images may not be automatically translated into text that can be read by screen readers. The presence of interaction elements that may only be reached using pointing devices is also a severe barrier for people with visual and some types of motor impairments.

Promoting the inclusion of everyone in regular education environments has been a strong concern for educators as well as for governments. Similarly, promoting the inclusion of everyone, regardless of disability is a very important issue to be dealt in the context of e-learning environments.

Making e-learning systems accessible has been an important challenge. Indeed, many web based e-learning systems fail to adhere to web accessibility guidelines (Freire, Tanaka, de Lara, Rocha, & Fortes, 2007; Guenaga, Burger, & Oliver, 2004). The challenge to make these systems more accessible is even more serious when we think about new interactive technologies and synchronous multimedia resources.

A number of research reports details efforts to promote inclusion in e-learning. An example is the Notebook University Model Project (Klaus, 2004). The project aims, for example, the development of application specific services, which will support the production of ubiquitous e-learning applications. The Study Centre for Blind and Partially Sighted Students, involved in this project, dedicated attention to the special questions related to blind and visual impaired students. The centre investigates, for example, what to consider when preparing a course, issues with file formats used in higher education, use of multimedia, availability of documents, and others.

Other resources that can improve ubiquitous e-learning applications for blind uses are the proper adoption of screen readers and speech recognitions systems. Wald and Bain (2008) discuss how automatic speech recognition can support universal access to communication and learning through the production of text synchronized with speech. This involves assistance to blind, visually impaired or dyslexic people to read and search material.

Traditional desktop screen readers, like JAWS\(^1\) and Virtual Vision\(^2\), are already part of blind users’ life. Other efforts have been done to bring the screen readers to limited resources. For example, Chen, Tremaine, Lutz, Chung, and Lacsina (2006) present the AudioBrowser, which

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is built on a standard PDA with several features to make the interface accessible and usable by blind users. The interface uses a touch screen and buttons for input and non-speech audio and speech as output, allowing users to browse both stored information and system commands.

Another research field related to blind people inclusion is the development of learning tools to support teaching specific subjects. Rosas, Nussbaum, Strasser, and Csaszar (1997) describe an intelligent tutoring system that can support the teaching of reading and writing of Braille signs to blind children.

Although many efforts have been made to include blind users in e-learning environments, there is still a lack of research works about interactive and synchronous multimedia e-learning applications.

IWBs have become a usual resource in classrooms around the world. Slay, Siebörger, and Hodgkinson-Williams (2008) point some teacher's reports about the advantages of that technology, such as efficiency, flexibility, versatility, opportunity to access multimedia content, support to multiple needs within one lesson, and the ability to face the class whilst teaching, allowing teachers to maintain class control, which would be harder with a laptop, for example.

In face of the advances on the use of interactive technologies, such as the IWBs, making the new advances more inclusive is an urgent issue to be dealt with. In the next section, we describe the main points regarding our proposed approach for mediation in IWB-based systems.

3. An inclusive approach for interactive whiteboard-based system in e-learning environments by means of mediation

From the observation of the need to provide further support for accessibility in synchronous tools in e-learning environments for blind people, we have proposed an approach to help students with special needs to participate in distance synchronous learning sessions with a mediator.

Providing people with special needs with effective support to take part in lectures is a significant challenge even for traditional live classes. Many instruments used in classrooms may present barriers for people with different disabilities. For example, deaf students may not be able to receive information transmitted only by speech, in the same way that blind students are not able to receive graphical information contained in boards and projected presentations.

For many of these needs, educators usually rely on special staff, "mediators", to help overcome the restrictions of access with respect to some kinds of information media. The presence of a sign language interpreter is an example of a mediator to help students to be able to comprehend information that is transmitted by educators using speech.

In many schools and universities, teachers and lecturers usually count on support from staff of the “office for disability services” or other similar kind of support to adapt educational material. However, in many cases this adaptation has to be done well in advance before the classes, otherwise students with special needs may have access to content much later than their counterparts. For example, the provision of text equivalent is used in multimedia, closed captions for multimedia TV is a very suitable way to help people with hearing impairments to have access to live transmissions. This kind of approach is also very helpful as it enables a single mediator to help a very wide range of people.

The proposal of this work is based on the idea of providing infrastructure to provide mediation in synchronous e-learning sessions. The approach consists of both the provision of an environment for mediators to input content, and the provision of structure to have alternative exhibition of content, aimed at blind users.

The main advantage of the proposed approach is to enable students to have access to the content by means of direct access to the objects. Students are able to navigate through the content available in the IWB software, which are accessed according to the spacial disposition in the screen.

The mediator is responsible to add meaningful descriptions considering the method used by users to navigate, in a manner that content may be understandable in the best way. However, mediators and teachers should analyse beforehand the relative complexity of graphics and other elements that will be used in the session to evaluate whether the description of the objects alone may be enough for the complete understanding of the content. Tactile graphics or other technologies should also be considered as a complement for more complex graphics in conjunction with the descriptions provided for the elements in the IWB.

As a proof of concept, we have implemented this approach in an IWB software used in a virtual learning environment. Regular and digital boards are usually an unreachable educational resource for blind students in both live and distance learning environments, as it is widely used to sketch graphical elements in learning activities, which are not usually accompanied by proper textual descriptions. Thus, providing means for blind students to have access to the content presented on the board is a great advance to help them to participate effectively in the learning process.

The main actors involved in the learning process for this proposal are represented in Fig. 1. In regular scenarios, there is the presence of teachers and students who are able to perform a visual navigation through the graphical elements and that may interact with the board using pen-based/mouse interaction. In this proposal, we also take into account the role of a mediator who is able to add textual descriptions to visual elements used by the teachers. Hence, a blind student may be included and may be able to interact with “virtual elements” containing text descriptions via keyboard, and to navigate through the elements using a screen reader. In next section, we describe the implementation of this proposal in a prototype.

4. Prototype implementation

The proposed inclusive approach to enable blind students to have access to learning content in graphical IWB environments was implemented in the context of the Tidia-Ae Project. In the next subsections, we provide a basic background on the main features of the Tidia-Ae environment and the previously existing IWB software.

4.1. The Tidia-Ae project and portal

The Tidia-Ae is a collaborative e-learning project that uses Information Technology to the Development of the Advanced Internet (its acronym, in Portuguese, is Tidia-Ae, which from now on is called simply AE). The AE project aims at the research and development of open source e-learning tools in high-speed networks, which can be used in co-located and distance learning contexts.
The AE project started in 2004 and embraces several Brazilian research institutes. In 2007, the AE started a partnership with the Sakai project and adopted its framework for the development of e-learning tools. Fig. 2a shows the AE portal, with a course site (Fig. 2b) where users can access several e-learning tools, such as schedule, announcements, portfolio, chat, whiteboard, instant messenger, and so on. Fig. 2c shows our IWB software accessed through the course site, showing drawing buttons and annotations.

4.2. The interactive whiteboard software

The IWB software provides features to capture what we call pen-based electronic ink annotations, which are useful in several application domains (Pimentel, Cattelan, & Baldochi Junior, 2007). Considering an educational scenario, the IWB software can be used to capture
the instructor annotations during a lecture, to record these annotations and to allow them to be reviewed in the future. Users can interact with the IWB software using tablet PCs, IWB devices or a personal computer.

The IWB software provides a rich set of operations which allow the user to manipulate different ink colors and width, use predefined geometric forms, operations involving the copy, cut, paste, move and erase of objects; redo and undo, create new slides, duplicate existing slides or navigate through slides.

Considering an educational environment such as the AE (Section 4.1) the IWB software is a very useful tool for remote users to share annotations during and after class or brainstorming sessions.

By means of a web browser, users can log into AE and manage IWB sessions according to their role’s permissions, which can be the roles of instructor, teacher assistant or student. Instructors and teacher assistants of a course have write permission, whilst students can only watch the slides content. The IWB software allows the instructor to grant write permission to any given specific student at any moment of a synchronous session.

The IWB software was implemented as a Java application, using the Java Webstart technology. This allows the application to run in different platforms and operating systems.

One of the most important characteristics of the IWB tool, tough, is the possibility of being executed in distributed environments. This makes it possible for the tool to be used both in distance learning environments or in presence learning where students and teachers may share their annotations by means of the network.

The collaboration with the IWB tool is implemented by means of a communication service (middleware) (Pereira, Lobato, Teixeira, & Pimentel, 2008), which allows the exchange of messages between different instances of the application being executed in different computers. Each event that occurs in an IWB (e.g. object drawn, message sent, participant joined) is sent to the server, and is then transmitted to other connected users, as illustrated at Fig. 3.

4.3. Accessible descriptions in the interactive whiteboard software

The features of the IWB software are mainly related to the capture of drawing using pen-based interaction. This is a very challenging accessibility issue, since even texts are treated as images.

The use of Optical Character Recognition (OCR) or other techniques for text recognition in images could be feasible to provide accessible descriptions for text in the IWB. However, hand-written texts contained in an IWB may not be enough to help students with visual impairments to comprehend all the context of a class. In regular classes, the drawings and the arrangement of the elements on the board also provide very important contextual information that are essential to understand the content.

Therefore, providing students with the possibility of navigating through the descriptions of the elements in an IWB seemed to be a good technological approach for our proposal.

As described in Section 4.2, the version of the IWB software used in this project was implemented using Java technologies. Interface elements provided by the Java platform are not intrinsically accessible for screen readers. In order to be able to provide access for screen readers to content in graphical elements, it is necessary to assign “accessible contents” explicitly for each of them using the Java Access Bridge (JAB) API (Sun, 2009).

The JAB API provides an interface to assign accessible names and descriptions for graphical elements in a Java application interface. Even if a given element contains text (a button with a textual caption, for example), this content should be explicitly assigned to the accessible content. Although many development environments already provide support to automate this process, it may still lead to problems with interfaces with no proper accessible text descriptions, even in inherently textual elements.

The scheme used for the implementation of accessible context in the JAB API was a serious challenge to be dealt within this project. In this scheme, it is not possible to simply assign alternative texts to images contained in the IWB, as it would be done in Web pages. The images in the IWB are drawn within a bitmap oriented image canvas, which is treated as a single interface component.

The JAB API has another limitation regarding the use of interface components. Screen readers are only able to read the content of focusable elements. This means that it is not possible, for example, to assign accessible texts directly to field labels, descriptive texts and others. Thus, the description for these elements would have to be added to other focusable related elements, as a workaround.

Considering the limitations of the JAB API, the provision of accessible navigable descriptions for elements in the IWB was implemented by using additional focusable interface elements included on the screen. These elements are made invisible to other users.

A textual description may be assigned to one object in a drawing, or to a group of objects. Besides assigning a descriptive text, the mediator should also determine the position where the virtual element should be included within the graphical element it intends to describe.
The position is determined relative to the alignment in width and height of the original object, as indicated in Fig. 4, which contains the input data for the accessible descriptions to be informed by the mediator.

The accessible description virtual interface component is always of the size of one pixel, and its position is very important for the order of the reading and navigation of the content. When no arbitrary tab order is manually determined, Java scans the elements on the screen top to down, left to right.

In a live session, students will receive a new description automatically each time the mediator provides them with new content. This content should then be immediately read for students. After that, students are able to navigate through the content using the “tab” key. In Fig. 5, we have highlighted the position of each of the descriptions provided in a slide with the atmosphere layers. The position of each description is marked with a circle, and the associated description is also shown in the overlaid boxes. These descriptions are not shown

**Fig. 4.** Data input for accessible descriptions, containing the text to be included and positioning information. Window on top shows the inclusion of information relative to the word “Thermosphere”.

**Fig. 5.** Image of a slide overlayed with the corresponding textual descriptions for the graphical objects annotated by the mediator (the overlap is for illustrating purposes only).
visually in the actual interface. When users navigate through the interface, they may reach each of the elements marked, and then may listen to the description from the screen reader. The implementation of the features for accessible descriptions with direct access for user navigation presented a number of challenges. The use of objects drawn as bitmaps on a canvas makes it more difficult to provide accessible descriptions than to vectorised objects positioned at the screen. Besides, the implementation of the features for accessible description with the Java language still presents a number of limitations by the platform, including the fact that only objects that may receive focus are accessible to the screen reader. Finally, the inherent distributed nature of the tool also presented a number of challenges to implement the communication between the clients with descriptions provided by different users in a way that these annotations would be correctly related to their respective objects.

In next section, we describe the main related work and how the present work advances on previous existing gaps.

5. Related work

The use of interactive IWB tools to facilitate collaboration in learning environments has been reported in a number of works in the literature (Abowd, 1999; Berque, Johnson, & Jovanovic, 2001; Hansen et al., 2005; Shi et al., 2003). The proposals for IWBs involve the use of enhanced features for teachers and students in the classrooms. These new possibilities have been explored both in presence and distance learning scenarios. The main advantage of the use of IWB tools is to enable the capture and access of the content produced in a learning session. Most of these tools enable teachers and students to draw, upload slides, and to cooperate in the development of the content.

Being a relatively new technology, the effective use of IWBs in the classroom has been investigated by a number of research works (Hall & Higgins, 2005; Smith, Higgins, Wall, & Miller, 2005; Smith, Hardman, & Higgins, 2006). Many issues still seem to need more analysis regarding the use of IWBs, such as the need for training for teachers, the resistance for use of new technologies, costs, and other pedagogical issues. Nevertheless, IWBs have proven to be very promising in terms of providing new possibilities for educational scenarios.

However, addressing the issue of accessibility in these inherently interactive tools seems still to be a matter not thoroughly covered. When analysing a representative set of commercial IWB tools, we could observe that very few of them had any feature to support accessibility by screen readers. Among these tools, only Adobe ConnectPro (2009), the IWB in the Project EVO (2009) and Google OpenMeetings (2009) do not present features to support accessibility by screen readers.

From the tools investigated, we could find accessibility features provided by the tools AComm (2009) and Elluminate Live (2007)—we discuss these tools next.

AComm (2009) is a component used as a communication tool in the Atutor project. It was developed in Java and has some accessibility features such as the playback of some sound effect when a new message arrives and the fact that the users can draw on the AComm IWB using the keyboard instead of using a mouse. Moreover, the peer description feature allows any participant to describe the drawn objects, so a sighted user can type a text description of the content in the IWB that a blind person can listen to. Most of the features provided by the tool have alternative text for screen readers and may be operated by keyboard. The tool is mostly based on communication using the jabber protocol. The descriptions for objects drawn on the IWB are sent as text messages displayed in the chat box. The main drawback of this approach is that the manipulation of the descriptions by a blind user is only made by means of the chat dialog box, which may also contain other messages in the order they were sent, including both drawing descriptions by peers and other (chat) messages.

Elluminate Live (2007) is a commercial synchronous web conferencing and collaboration environment on which presentations and documents can be shared. The environment supports collaboration via text, audio and by means of an IWB. The environment provides some features motivated by the Americans with Disabilities Act (ADA), including keyboard access to menus and dialogs, closed captioning, enlarged video, user-defined color, screen reader compatibility, and others. It has an option to include speaker notes for imported presentation files. With this feature, it is possible to add accessible text for IWB slides for screen reader navigation. Although it is possible to provide accessible descriptions for slides in this tool, it is only possible to provide one accessible description for the entire slide. Another drawback of this approach is that these descriptions have to be prepared beforehand, and it is not possible to add descriptions for objects that are drawn during a live session.

The tools AComm and Elluminate have provided important advances to the accessibility of IWB tools. Providing some means to have descriptions which are accessible to screen readers is the main advance for blind users. However, in the case of Elluminate, these descriptions have to be provided by means of text comments for the whole slide, and the insertion of descriptions for objects that are drawn in live sessions is not possible. The AComm tool, on the other hand, provides means to insert descriptions for objects drawn in live sessions, but it is not possible to manipulate these descriptions directly. The descriptions are not linked directly to the objects drawn, but are listed in the chat window together with other messages, which may make it difficult for blind users to filter them and explore the IWB according to the spatial distribution of the objects.

The implementation of the proposal reported in this paper builds on previous proposals by providing means to include accessible descriptions in live sessions for IWBs and enabling direct manipulation. The use of the underlying communication infrastructure makes it possible to keep the descriptions associated to the objects, in a way that the descriptions may be later navigated using a screen reader and explored according to their spatial distribution.

In next section, we describe a simulation of a scenario of use of this feature with a blind student in a remote class which uses the IWB software.

6. Case study scenario

Once the first version of the prototype was concluded, an early evaluation with a blind user was conducted. This experiment was designed as a qualitative study with the goal of identifying the perception of a real blind user of the use of an IWB.

In the expected scenario of the use of the IWB software in distance learning, students may be located in distributed locations. For the design of this experiment, we considered the situation in which the student and the teacher would be in different places. Although this possibility was not explored in this scenario, other synchronous communication tools could be used, such as video and audio based communication tools.
The scenario we imagine for the use of an IWB software would involve students with different abilities using different technologies. In Fig. 6 we show an illustration of this scenario. The teacher is giving a lecture remotely using an IWB with pen-based interaction, one student interacts with the content using a tablet PC and a blind student is able to listen to the content by means of a screen reader, after a mediator provides him with accessible textual descriptions.4

6.1. Materials and methods

For the case study proposed, we used a short Geography class on atmosphere and the layers of the Earth. This class contained two slides: the first contained the names of the atmosphere layers and the second the names and the structure of the layers inside the Earth. The image of the first slide used is described in Fig. 5.

The main software technological resource used was the IWB software developed and previously described in this paper. The teacher used an instrumented classroom with an IWB device on the wall. The mediator used a regular personal computer, and the blind student used a personal computer with the Brazilian screen reader Virtual Vision.

Before the session started, the teacher and the mediator had a meeting to discuss the main topics that would be covered, and a short description of the main graphics and images that would be included. A list with a short description for each element that would be drawn by the instructor was made available to be used by the mediator. The textual description for each element should be input by the mediator as soon as possible after it is drawn by the teacher.

The test was conducted as an early informal usability evaluation using the ”Think Aloud” Protocol van Someren, Barnard, and Sandberg (1994). The participant was asked to say aloud every impression he had whilst using the software. The blind participant was informed in advance that the aim of the study was to evaluate the software and not he as the user, and that we would keep his anonymity. He was also informed that he could interrupt the test at any time if he wanted.

An evaluator was with the user to provide the guidelines to him before and after the experiment and to take notes on the main issues the user would raise. After the session, a short interview was conducted by the evaluator with the aim of investigating:

• Previous experiences of the user in regular and distance learning scenarios using IWBs.
• Previous experience with screen readers.
• Main impressions from the user of an accessible IWB.
• Main problems identified with the prototype.

In next section, we describe the main results obtained from the evaluation.

7. Results and discussion

7.1. Technological results

It is important to highlight that the implementation of an IWB software accessible to blind students itself is an important technological result. As stated in Section 2, it has been a great challenge to advance in the provision of inclusive education. Although the solution is not yet completely accessible for different groups of users, such as partially sighted and people with motor disabilities, the provision of means to make IWBs accessible to blind students is an important initial achievement.

However, from the observations of the difficulties found during the implementation, we may point out other issues that should be dealt with. The use of the Java platform was a serious limitation for this project, as the accessibility resources for Java interface components are

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4 In this figure, the picture of the actual blind student who took part in the experiment was not included in order to ensure his anonymity.
still very poor. The wide use of Java as a platform for the development of several applications, including educational ones, makes it urgent that its available accessibility resources are improved.

Several problems identified in the usability evaluation could be improved should the Java platform provide more efficient accessibility resources. The need to use buttons to navigate with “Tab” was one of the main problems identified. If textual elements in Java interfaces could be made accessible, it would be possible to use the arrows to navigate, making the interface more familiar with what blind users are already used to.

7.2. Results from the case study

Although it was not possible to conduct a wider experiment with more users due to limitations in the recruitment, it was possible to identify interesting findings in the case study.

The blind user that participated in the case study had recently concluded his secondary level studies in a Brazilian public school. According to his comments in the interview, having access to the content the teacher displays in the board was always a challenge for him. Whilst studying at school, he frequently had to ask the teacher and his colleagues to provide him with further explanations about what was drawn. The problems with the board were even more serious in Math, Geography, Biology and other classes where the teacher would always make reference to graphical elements drawn on the board, as it may be observed from his next quotation:

“I had never had access to what was written on the board before. It was terrible for me when the teachers made references to anything that was written or drawn in the board. Particularly in Math classes, when the teachers were explaining about equations, they always made references to one or another side of the equation, and I could never figure out what they were talking about.”

Even though this user was already used to navigating through Web pages and other contents using a screen reader, being able to navigate through the content on the board was a complete novel experience for him:

“It is like being able to play with something I had been deprived from for my whole life.”

From the pedagogical point of view, the participant complained about the amount of information that was displayed. He claimed that more information could be provided for each element.

During the experiment, the observer also noticed that the lack of further contextual information was a problem for the user in several moments. There should be further information about changes that had occurred, such as the start of the session, the moment when the teacher leaves and when the current slide was changed.

The participant also complained about the limited control over the interaction. Although it is interesting that the content is always displayed as soon as it is provided, it may disturb the user should he be listening to the description of another element and be interrupted by a new one.

The use of other communication resources such as chat and audio of the class was pointed out as important improvements to be investigated. The implementation of the integration of such features with the IWB software is being carried out in the context of other project developed within this research group.

From these problems, we intend to implement more improvements in next versions to make it possible to users to have further control over the interaction and personalize the settings regarding the moment in which the contents should be read.

In general, we observed that the user could interact with the IWB overall. The positioning of the elements was very important to make the reading of the elements in a logical order for the participant to understand the context. However, more information about the actual positioning could be provided, such as providing the positioning of each element in relation to others’ and informing relative distances.

Besides observing the impressions from the participant, after the experiment we also asked the teacher and the mediator to provide their impressions from the experiment and the use of the IWB software. Following we transcribe the impressions provided by the teacher:

“As a teacher, it is a satisfaction to know that all my students are able to access the content I am developing using the board. With the accessible IWB feature I do not need to worry anymore about giving a special attention to blind students during the class, when I explain something using the board. Instead of being over concerned about how to include blind students during the class, I think I should spend some time before class giving some explanations to my assistant (mediator), regarding the content of the class. It could make the work of the mediator faster during the class and improve the quality of the annotations to the students.”

Following we transcribe the impressions from the mediator, which role is to write accessible descriptions about what is begin drawn and annotated by the instructor on the board during the class:

“In the experiment, as a teaching assistant (mediator), I made my annotations based only on the short descriptions I had from the previous planning and based on my own impressions about what was being drawn and written by the instructor. I noticed that my annotations could have been more efficient and helpful to the student if I had talked further to the teacher about the class and about what to write in each slide. Even being an expert about the class subject, it was hard to know what the instructor intention was when he started a new slide. During the class, the annotations I made were the only way to reveal to that student what the instructor was doing on the board. Hence, planning the slides annotation is quite important if we want to give a good understanding of the class to the student.”

As we may observe from the transcription of the impressions from both the teacher and the mediator, the previous discussion about the topics that are going to be covered in the class between them both is crucial. Although only a short discussion about the content of the class was conducted in this experiment, we may point out that this activity is extremely important for the good understanding of the class and for the quality of the content provided to blind students.

The mediator plays a key role to provide blind students with good alternative content. Thus, it is also very important that the mediator is well prepared and well trained to perform his job properly.
Although the case study developed in this study was performed in a distance learning environment, we suggest that the use of such approach could be very effective for co-located learning environments. Should IWBs be used in these scenarios, the presence of a mediator would be very helpful for blind students to better understand the content of a class.

7.3. Limitations

The proposal presented in this study presents significant contributions to the provision of accessible descriptions to graphical elements in IWBs with direct access for blind users. The implementation of a prototype as a proof of concept and a preliminary test have shown the feasibility of the approach.

It is worth highlighting, though, that the extension of the application of such approach should be carefully analysed by educators in the context of a pedagogic plan. A careful plan and organisation between a teacher and a mediator is crucial to help provide useful annotations that would effectively help blind users interact and better understand the content with which they are interacting.

However, educators should be aware of the limitation of the medium itself in terms of what can be provided for students. For complex graphics, the complementation of materials such as tactile graphics is essential for a full learning experience for blind students. Teachers, disability officers and other staff involved in the educational process should carefully evaluate in which cases each medium should be used and how to coordinate and combine them to provide blind students with the most they can have from the interaction with learning materials provided by means of IWBs.

The contribution of this study is also limited to the proposition of an implementation approach and an initial evaluation for mediation and direct navigation through descriptions for graphic elements. More detailed studies on the pedagogical issues connected with this approach should be carried out to better define how students can get the most from this technological solution.

8. Conclusions and future work

E-learning systems are important resources to provide students with augmented opportunities for learning. Making e-learning tools more accessible to students with different abilities and disabilities is crucial to make these environments more inclusive.

In this paper we have presented a proposal of an inclusive approach for synchronous IWB software tools for blind students. This approach is based on the provision of features to include accessible interactive textual descriptions provided by a mediator.

This proposal is a very important contribution towards the evolution of the accessibility for synchronous communication tools in e-learning. Making IWB tools accessible has been a significant challenge for researchers and educators. This proposal has exploited the well known technique of mediation used in other educational contexts.

From the case study conducted, we could observe that this proposal may have good impact on the way that blind students interact with graphical contents in learning activities with IWBs. The lack of support for these students to have access to graphical content in board-based learning in both distance and co-located education has been a serious issue for the inclusion of these students, as it is a widely used resource.

Nevertheless, in our case study we could observe that the success of this approach depends deeply on a well established preparation protocol. Mediators and teachers should be aware of the needs of the students and should work in synergy during the preparation of the classes.

In the case of distance learning scenarios, the provision of further integrated and synchronized resources such as chat and audio content of the classes would be very helpful for students. However, the integration between the different learning resources and the ways to provide students with means to control them are still challenges to be investigated.

From the technological point of view, the future work we intend to carry out involves the creation of players for previous sessions and the use of the approach of mediation for other applications, such as live sessions with audio and video.

As a next step, we will perform a broader study with a larger group of blind users in both experimental and real scenarios. The main goal of this future study will be to investigate the aspects related to the usability and accessibility of the proposed software and the pedagogical implications of the use of this approach.

The possibilities of the use of this approach should be further investigated to be adapted and applied for other types of disabilities, such as for partially sighted, deaf and people with motor disabilities.

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