Maximising the affordances of new and emerging online e-learning technologies for learners with special needs

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The introduction of distance learning in the 1990s facilitated more flexible learning options aimed at reducing inequities arising from geographical and social isolation. In more recent times there has been increasing interest in the affordances of information and communication technologies (ICTs) such as Web 2.0 and 3D virtual learning environments and their potential for engaging learners from diverse backgrounds. However, such new and emerging e-learning technologies pose more significant accessibility challenges than traditional learning approaches given their use of rich media and their dynamic nature. This paper provides an overview of the potential of new and emerging ICTs for supporting the goals of inclusive education and providing a more enriching learning environment for students with diverse learning needs. The accessibility challenges posed by these technologies are explored and strategies for addressing these concerns discussed. The preliminary findings of research involving the design and development of an open source accessible Web 2.0 and 3D virtual learning platform, and associated guidelines to support the development of teaching resources that cater for diverse student learning needs are reported. The implications for the design of more accessible e-learning teaching and learning resources are discussed and areas for further research are proposed in the final section of the paper.

Keywords: e-learning, special needs, affordances, Web 2.0, 3D virtual learning environments

Introduction:
Online Information Communication Technologies (ICTs) make accessing information any time, any place and using any device a reality for more than a quarter of the world's population (Wood, 2010a). Recent figures on Internet usage suggest that in June 2010 there were more than 6.8 billion Internet users representing 28.7% of the global population (*Internet usage statistics: The big picture*, 2010). The growth in mobile and fixed broadband sectors has also continued to increase with mobile subscriber penetration estimated as 70% at the global level (*Global – key telecoms, mobile and broadband statistics*, 2010). Not surprisingly, as Johnson et al report (2011), this growth in access to the Internet through mobile devices has led to increasing demand for flexible learning options enabling students to work, learn and study, whenever and wherever they want (Johnson et al, 2011). Such access can also improve communication and increase the independence of students who have disabilities (Coombs, 2010) and those who are geographically or socially isolated (Wood, 2010a).

This increasing access to ICTs and the growing awareness of the importance of digital media literacy, combined with the changing demographic profile of learners who have grown up with digital media has led many teachers to seek innovative solutions to harness the enthusiasm of young learners while also enhancing their ability to collaborate, communicate and problem solve augmented by digital technologies. One of the emergent trends in response to these demands has been the shift away from traditional models of teaching based on a transmission mode of delivery to more flexible learning approaches characterised by collaboration, connectivity and constructivism (Paas & Creech, 2008). Web 2.0 and 3D simulated learning environments have emerged as powerful ICTs for supporting these pedagogical approaches in teaching and learning. There is also growing interest among teachers and curriculum developers in the affordances of a range of emerging technologies including cloud computing, augmented and gesture based interfaces, location-based learning, smart devices (Johnson et al, 2009; Johnson et al, 2010; Johnson et al, 2011) and learning analytics (Johnson et al, 2011).

Despite the potential of these e-learning technologies, several authors have cautioned about potential challenges in adapting new and emerging technologies within the curriculum (Carlson 2005; Hayes, 2006; Kennedy et al. 2007, 2009; Mason and Rennie 2008; Mulholland 2008; Oblinger 2008, Wood et al, 2010). One of the more significant challenges, yet less evident in discussions about the pedagogical affordances of e-learning technologies, is the need to ensure that current and emerging technologies are accessible to a diverse student audience including learners with special needs. Just as these technologies can facilitate increased social participation of learners with special needs, those who can benefit the most from such collaborative, rich media experiences may be further disadvantaged by the technological barriers to accessibility imposed by such platforms (Wood, 2010a, 2009a).

This paper begins with a review of the literature addressing the changing demands of the knowledge-based society. The affordances of educational technologies are explored with particular focus is given to the role of participatory Web 2.0 and 3D simulated learning environments in supporting creativity, collaboration, constructivism and connectivism (Siemens, 2005). The accessibility challenges associated with current and emerging technologies are discussed and existing solutions described within an inclusive education framework.

The second major section of the paper describes research undertaken by a team of Australian researchers led by the University of South Australia, which has been supported by the Australian Learning and Teaching Council. This research involves the design and development of an open source accessible 3D simulated learning environment and associated Web 2.0 application. The technical challenges and solutions encountered through the design process, and findings from preliminary testing are reported.

The concluding section proposes future directions for research and explores the potential for emerging technologies to “level the playing field” for diverse audiences, especially learners with special needs.

Background

While access to both technology and content is an essential component of e-learning, the effective use of e-learning technologies requires both an understanding of the different affordances of e-learning technologies (Anderson, 2008; Conole & Dyke, 2004; McLoughlin & Lee, 2007) as well as the knowledge required to ensure the online learning environment is accessible to learners with special needs. For the purposes of this paper, and drawing on the work of Norman (1999) and Salomon (1993, p. 51), the term “affordance” is defined as the perceived and actual properties of an e-learning technology that determine how that technology may be used effectively in online learning. The term “accessibility” is defined in its broadest sense: accessibility is about ensuring that anyone, using any browser or device, is able to access any content on the web. This definition is consistent with Letourneau’s (2009) position that accessibility ought to be concerned with ensuring that all users (regardless of ability) can access virtual environments using current and legacy devices as well as emerging non-browser technologies, while also gaining full and complete understanding of the content of those environments. In this first section, the affordances and benefits of e-learning technologies aimed at supporting these goals are discussed.

Affordances of e-learning technologies

The demands of our increasingly complex world and the challenges posed by an uncertain future demand a radical departure from the routine problem solving tasks required in the information age (Florida, 2003). The new “conceptual age” (Florida, 2003) requires graduates who are able to undertake creative work in environments that are increasingly dependent on digital technologies (Cunningham, 2006). This trend toward increasing emphasis on creativity, problem solving and providing a more participatory approach to learning augmented by digital technologies requires a new paradigm in teaching and learning; one that leverages the digital literacy of our changing student demographic. While advances in e-learning technologies have the potential to transform learning “in ways previously unimaginable” (*Essential student learnings for 2020 through advanced technologies*, 2011), several authors have expressed concern about the failure of curriculum developers to harness the affordances of e-learning technologies in ways that achieve the paradigm shift demanded by the knowledge-based economy (Herrington, Reeves & Oliver, 2010; Paas & Creech, 2008; Underwood, 2009). Nevertheless, researchers are beginning to cite evidence demonstrating the positive impact that digital technologies can have on learning outcomes when used effectively (Underwood, 2009). In the following sections, the affordances of Web 2.0 and 3D virtual simulated learning environments are explored.

Web 2.0 e-learning technologies

While there is considerable debate regarding the definition of Web 2.0 (Alexander, 2008) and even the origins of the term, most authors suggest the term can be attributed to Tim O'Reilly (2005a) who described Web 2.0 as a set of principles and practices that harness collective intelligence. Web 2.0 applications rely on rich user experience, user participation, dynamic content, meta data and Web standards utilising technologies such as AJAX (incorporating XHTML, CSS, XML, XLST and JavaScript), syndication (eg RSS) and RDF (Best, 2006). Such technologies are gradually finding a place in e-learning including the use of Wikis, Blogs, photo and video sharing sites, podcasting, collaborative bookmarking and social networking applications. Reo (2006), citing from a 2003 blog entry, suggests that social software augments social and collaborative abilities through mediation; a position echoed by O'Reilly (2005b) who argues that Web 2.0 is blurring the boundaries between people and the machine as communication and our social network is increasingly computer mediated. Bruns (2008) has proposed a new term "Generation C" to define the core capacities required of Web 2.0 learners; the capacity to be creative, collaborative, critical, combinatory, and communicative (Wood et al, 2010). The benefits of engaging students in such collaborative, connected activities are well documented (Collis, 2008; Downes, 2005; Franklin, 2007; Mason & Rennie, 2008), though there remains a paucity of empirical evidence demonstrating the efficacy in teaching and learning. As Mason and Rennie (2008) point out, much of the current evidence is drawn from a range of Web 2.0 cites rather than peer reviewed publications.

3D virtual learning technologies

A 3D virtual learning environment extends traditional web based online curricula by providing an online three dimensional constructed space in which students, represented by avatars (3D visual representations of themselves), can learn, create, explore, gather information and undertake research collaboratively and individually in their simulated virtual world.

3D virtual worlds have attracted growing interest from educators (see for example Gregory et al, 2010) who are keen to engage their students in a game-like environment that offers the potential for increased flexibility, enhanced collaborative opportunities and a safe environment for experiential learning activities (Wood & Hopkins, 2008). These environments are increasingly being used for a range of activities including presentations, discussions, role plays and simulations, historical re-enactments, games design, dramatic performances, creative arts and business modelling. 3D virtual learning environments enable learners to interact with information from a first-person perspective (Dickey, 2005) and offer unique opportunities for students to engage in simulated learning experiences not easily achieved in a non-mediated learning environment. Such activities can prepare students for future employment without the constraints of "real world" industry placements (Chen, 2005; Jarmon et al, 2009; Wood, 2009b). Moreover, as several authors note, 3D virtual worlds such as *Second Life* can facilitate communication skills (Robbins, 2007), collaboration and constructivism (Clark & Maher, 2003), and can also increase students' understanding of cultural differences and other aspects of diversity (Lee & Christopher, 2006).

Many educators have expressed concerns about the use of virtual worlds to merely transfer existing pedagogical approaches from the classroom to the virtual (Girvan & Savage, 2010; Savin-Baen et al, 2010). As Pfeila, Angb and Zaphiris (2009) suggest, virtual worlds should not be used as a substitute for face-to-face interactions, but rather, for activities that are not possible or easy to undertake in "real" life. Similarly, Salmon (2009) suggests teachers need to experience 3D virtual world environments to fully appreciate the pedagogical affordances they offer beyond traditional approaches to teaching and learning.

Accessibility challenges

Despite the pedagogical affordances of Web 2.0 and 3D virtual learning environments and the potential for accessible design to "even the playing field" for students with disabilities, a range of accessibility challenges have been identified in relation to Web 2.0 applications. A review undertaken by AbilityNet in 2008 (State of the eNation, 2008) reported that most of the social networking websites reviewed were difficult or impossible for people to use. None of the sites were found to satisfy a base level of accessibility. The issues identified include:

- Lack of alternative text for images;
- keyboard accessibility limitations;
- Accessibility problems created by the CAPTCHA system used as part of the initial registration process;
- No mention of the importance of captions or transcripts for user created video content;
- Use of fixed font size for text;
- Use of JavaScript for some features that cannot be accessed without JavaScript.

Gibson (2007) suggests that while the web will eventually become more accessible with increased accessibility built into web browsers, the next generation of the web (Web 2.0) presents further challenges for people with disabilities as these new interaction models are "'pushing the limits of the technologies of the web and the ability of assistive technologies to interpret the changing face of the web". Both Gibson (2007) and Zajicek (2007) note the major challenges imposed by the use of Asynchronous JavaScript and XML (AJAX) to create dynamic Web 2.0 pages and Zajicek (2007) identifies several concerns including:

- Increasing use of video content within Web 2.0 sites to augment or replace web content;
- A reliance on fast download times, which are unattainable for those on lower incomes and/or those living in remote locations who rely on dial-up;
- The inaccessibility of dynamic websites that rely on AJAX;
- Use of CAPTCHA to deter bots from accessing sites.

Just as Web 2.0 applications pose accessibility challenges, there is widespread agreement that there are significant technological barriers associated with highly visual environments such as 3D Virtual Worlds (Qi, 2007; Hickey-Moody and Wood, 2008; Wood, 2010a) These issues are explored further in a subsequent section of the paper.

Inclusive education and universal design of e-learning curricula

Inclusive education has becoming an increasingly important policy issue worldwide in response to international initiatives such as the United Nations Millennium Development Goals (MDG), Education for All (EFA) and the United Nations Convention on the Rights of Persons with Disabilities and its Optional Protocol, which was adopted on the 13th December 2006 and opened for signature on 30 March 2007. Rispler-Chaim (2007) suggests, these initiatives build on a foundation of related human rights policies including the Universal Declaration of Human Rights (UDHR) of 1948, the International Covenant of Economic, Social and Cultural Rights (ICESCR) of 1976, the International Covenant on Civil and Political Rights (ICCPR) of 1976, the Declaration on the Rights of Mentally Retarded Persons of 1971 and the Declaration on the Rights of Disabled Persons, proclaimed by the General Assembly of the United Nations on 9 December l975. There are now 147 signatories to the Convention on the Rights of Persons with Disabilities, 90 signatories to the Optional Protocol, 98 ratifications of the Convention and 60 ratifications of the Protocol (*UN Convention on the Rights of Persons with Disabilities: Status of Signatories and Parties,* 2011; *UN Optional Protocol to the Convention on the Rights of Persons with Disabilities: Status of Signatories and Parties*, 2011). Australia was the first Western country to ratify the convention in July 2008. Saudi Arabia ratified by the Convention and the Optional Protocol in June 2008, and Ghaly (2010) and Gaad (2011) point to the growing interest in the rights of persons with disabilities and inclusive education practices across Islamic countries in the Gulf and the Middle East.

However, while many countries support the goals of inclusive education in principle, there are many challenges facing teachers charged with this responsibility (Gaad and Thabet, 2009 cited in Gaad, 2011) including lack of knowledge, limited resources, few opportunities for training, and lack of appropriate facilities. In a knowledge-based society, one of the most critical areas of concern in achieving inclusive education relates to the design of accessible e-learning curricula. Inclusive design (also referred to as "universal design" and "design for all") has emerged as an important set of guiding principles for the design of accessible online content, and has direct relevance for teachers concerned with the design and development of accessible e-learning materials. The key elements in universal or inclusive design are said to include providing interoperability, providing accessibility to users with disabilities and providing features that support customisation and localisation features for people from different countries and cultures (Usability First, 2004). In the following sections, three relevant initiatives that have led to the design of guidelines that can support teachers in the development of accessible e-learning curricula are described.

The release of the World Wide Web Consortium's (W3C) W3C Web Accessibility Guidelines (WCAG) in 1999 led to a new focus on addressing Web accessibility issues based on an inclusive or universal design approach. These W3C guidelines provide designers with the means for ensuring that the Web sites they create are accessible to a broad range of users, including those with visual impairments, hearing impairments, mobility impairments and learning disabilities. The updated Web Content Accessibility Guidelines (WCAG 2.0) became an official W3C standard in 2008. The WCAG 2.0 guidelines are based on a "technology-neutral" perspective and can be more readily applied to new and emerging e-learning technologies such as 3D virtual worlds, cloud computing, augmented and gesture based interfaces and mobile devices. There are four overarching WCAG 2.0 design principles. Online content must be: 1) perceivable (ie information and user interface components must be presentable to users in ways they can perceive); 2) operable (user interface components and navigation must be operable); 3) understandable (information and the operation of user interface must be understandable); and 4) robust (content must be robust enough that it can be interpreted reliably by a wide variety of user agents, including assistive technologies).

The principles of universal design were adapted by the Center for Applied Special Technology (CAST) and developed into a Universal Design for Learning (UDL) framework, which is of particular relevance to the design of inclusive e-learning materials. The Universal Design for Learning (UDL) framework is based on three primary principles: 1) providing multiple means of representation to accommodate different learning styles and needs; 2) providing the same information through different sensory modalities (e.g., through vision, hearing, or touch); and 3) providing information in a format that will allow for adjustments by the user (e.g., text that can be enlarged, sounds that can be amplified) (UDL cited in Coombes, 2010).

The IMS Accessibility Project Group has also developed guidelines more focused on the needs of the distributed learning community and aimed at specifically addressing the challenges that exist in online education. As Barstow, McKell, Rothberg, and Schmidt (2004) explain, these guidelines are not intended to replace existing standards and guidelines, but rather, to provide additional information and solutions, which are more specifically relevant to the design of accessible e-learning curricula. The IMS guidelines are based on six principles: 1) allow for customisation based on user preference; 2) provide equivalent access to auditory and visual content based on user preference; 3) provide compatibility with assistive technologies and include complete keyboard access; 4) provide context and orientation information; 5) follow IMS specifications and other relevant specifications, standards, and/or guidelines; and 6) consider the use of XML.

These three sets of guiding principles have formed the basis for the design and development an accessible 3D virtual learning environment and related Web 2.0 application through funding support provided by the Australian Learning and Teaching Council. The next sections describe the research design, preliminary findings and the implications for further research.

Methodology

Research Questions

Our research questions for the project are:

- What are the features and limitations of 3D virtual worlds for people with disabilities?
- What are appropriate techniques for designing usable and accessible interfaces to 3D virtual worlds?
- How can accessibility solutions to 3D virtual worlds enhance the learning experience for students with disabilities?
- What adaptations are required to extend accessibility solutions in closed 3D virtual world platforms to open source 3D virtual world platforms?

- What are the challenges and solutions required to adapt the environment for use in developing countries with limited ICT infrastructure?

The research design involves:

- Reviewing the existing literature into the usability/accessibility of current interfaces to 3D virtual learning environments.
- Undertaking ethnographic research involving participant observation of users' interactions and conducting interviews with individuals who identify as disabled in the 3D virtual world, *Second Life*.
- Trialing selected undergraduate courses in 3D virtual learning environments to identify the pedagogical benefits as well as the accessibility and usability issues relating to these technologies.
- Developing guidelines for interface design based on the World Wide Web Consortium's (W3C) Web Content Accessibility Guidelines 2.0 (2008), IMS Guidelines (Barstow, McKell, Rothberg & Schmidt, 2004) and UDL Guidelines version 2.0 (See Coombes, 2010).
- Adapting technical solutions developed for 3D virtual worlds such as *Second Life* to an open source Web 2.0 and 3D virtual learning solution.
- Conducting trials of the platform in a range of courses and with users who have physical, sensory and/or cognitive disabilities.
- Extending the trials to rural schools in developing countries to identify technological challenges and solutions for the use of these technologies in regional areas with limited infrastructure.
- Modifying the platform based on the findings from trials and making the platform available through open source to the community.

The study involves several stages, the first three stages of which have been reported elsewhere (Fewster & Wood, 2009; Fewster, Chafer & Wood, 2010; Hickey-Moody & Wood, 2010, 2008; Wood, 2010a, 2010b, 2009a, 2009b; Wood, Morris and Ussery, 2009, Wood & Hopkins, 2008). The following sections report the outcomes of our research into identifying the accessibility challenges, existing solutions and the design and development of the accessible 3D virtual learning environment based on inclusive design principles.

Results

Accessibility challenges identified

The first stage of the project involved ethnographic research conducted with people who identified as being disabled in the 3D virtual world known as *Second Life*.

Participants for the ethnographic stage of the study were individuals who identified as people with disabilities and responded to a recruitment "note-card" distributed to various disability groups in *Second Life*. Recruitment notice boards were also set up on SIMs (virtual regions) associated with these disability groups. The project website provided additional information about the project and could be accessed via a link embedded in the recruitment material. The main process of data collection involved participant observation and interviews using either text chat or audio-recordings for ease of analysis. The participants were not identified in the transcripts and resulting analysis or research outputs. The data material was made available to any of the participants on request and participants were advised that their participation was voluntary and that they could withdraw from the study at any time.

As reported by Wood, Morris and Ussery (2009) and Wood (2010a), our review of the literature and the findings from ethnographic research undertaken in *Second Life* identified the following accessibility limitations of 3D Virtual Worlds:

- The log-in screen of *Second Life* is not accessible for users who are visually impaired and rely on screen reader software.
- The local chat window in *Second Life* is not accessible to screen reader software.
- The user interface of the *Second Life* client is not accessible to screen reader software and there is limited support for alternative accessing devices.

- User generated content within *Second Life* is not accessible to visually impaired users.
- Tab-index needs to be incorporated to provide a logical order between links and options.
- There is need for provision of an audio message and a text list of avatars in the vicinity of user's avatar.
- A simple author solution is required that will enable users to add descriptive labels for all objects and longer descriptions for posters and slides containing text in image format.
- There is a need for synchronised streaming captions for videos.
- There is also a need for text transcriptions for streaming audio.

Survey of existing solutions
While Web 2.0 and 3D virtual worlds create greater challenges given their use or rich media and their dynamic nature, it is nevertheless possible to apply many of the principles of usable design to the development of such social networking applications. Gibson (2007) notes that that while accessibility guidelines were not in place when the Web first emerged and there is still much work to be done to make Web 2.0 fully accessible, new specifications can be added to these applications using APIs (extended accessibility application interfaces). Moreover, as Gibson elaborates, Accessible Rich Internet Applications (ARIA), which is a specification being brought forward by the W3C Web Accessibility Initiative's (WAI) Protocols and Formats Working Group is designed to enable assistive technologies to better represent user interface components and dynamic interactions to the user. Zajiceck (2007) suggests that the challenges created by the use of AJAX technologies to create dynamic pages can be addressed by following HIJAX principles, in which AJAX technologies are formed as an additional, optional layer on top of the html mark-up (Moonan, 2008).

Tim Berners-Lee also points to the potential of "marshalling the community" to improve the accessibility of Web 2.0 sites, suggesting in an interview with Out-Law.com (2006) that in the spirit of Web 2.0 collaboration, the community could provide captioning for video blogs. There are already several exemplary initiatives including Project readOn, a community committed to making online media content to all, which has created a streaming media caption player and provides professional captioning services, and the CulturAll 2.0 group which is progressing five projects aimed at improving the accessibility of Web 2.0 applications. YouTube video site now provides users with the ability to caption their videos and Google has a range of services including GAUDI (Google Audio Indexing), which uses speech technology to find spoken works inside YouTube videos and Google's new accessible search engine, which prioritises results that are accessible to visually impaired.

Virtual worlds such as *Second Life* can also be made more accessible to those with cognitive and sensory disabilities. There have been some important initiatives, many of which have been developed by the residents of the communities themselves. These include the development of browser based alternatives that enable users to access these worlds via the Web rather than a special client application (for example Ajax Life and Movable Life) and the use of Internet Relay Channel (IRC) enabling those who cannot access the virtual world to still participate in meetings using IRC via a Website.

Design and development of an accessible 3D virtual learning environment
Informed by the outcomes of our literature review, ethnographic research with people who identify as disabled and trials in several courses at the University of South Australia, the following design features have been identified as essential for an accessible 3D virtual learning environment (see also Wood, 2009a):

- interface able to support a range of inputting devices
- inclusion of styles enabling the customisation of type according to size and colour
- tab-index incorporated to provide a logical order between links and options
- a text-to-voice feature for chat
- provision of an audio message and a text list of avatars in the vicinity
- option to turn off graphics

- requirement for users to add descriptive label for all objects and longer descriptions for posters and slides containing text in image format
- providing text note cards for all objects containing a significant amount of text in graphic format
- synchronised streaming captions for videos
- text transcriptions for streaming audio
- conversion of voice to text that is exposed to screen readers
- inclusion of user help functions
- potential to interface with wearable computers
- Web browser alternatives to client viewers
- ensuring that the accompanying website is accessible

The solution under development aims to incorporate these accessibility features and builds on the exemplary work already underway in virtual worlds including the design and development of Max Voice technology as part of the virtual guide dog project undertaken by Virtual Helping Hands Inc. While a detailed description of the design solution has been published elsewhere Wood (2010a), the core components to the accessibility solution are reported briefly in this section.

There are two main components to the system: 1) the integration of text to speech and accessible interface controls in the open source 3D virtual learning client, which has been called Access Globe; 2) the design and development of a Web 2.0 site, which enables users who are unable to access the 3D virtual learning environment to log into the website and participate in real-time in any sessions being conducted in the virtual world.

Users logged into the 3D virtual learning environment can type text into the chat window within the Access Globe interface and they can hear that text read aloud, as well as the text messages from others participating in the chat session. The text chat is sent via http requests to the web server through a Cold Fusion gateway page and the data stored in a MySQL database. Similarly, any slides being displayed ‘in world’ are sent as images and text equivalents to the server.

On the web side, users log into the site and are authenticated. Asynchronous JavaScript and XML (AJAX) is used to poll the database and identify any new content that needs to be displayed via either a refresh or append command to the appropriate element within the page. However, as our initial tests with users with disabilities identified, and as Thiessen (2009) notes, it is very difficult for Assistive Technologies (ATs) to understand Document Object Model (DOM) events in AJAX applications. To resolve this issue, the W3C’s WAI Accessible Rich Internet Applications Suite (WAI-ARIA), which provides a framework for adding attributes to identify features for user interaction, has been implemented. As the WAI-ARIA site explains, ARIA makes it possible to map controls, live regions, and events to accessibility application programming interfaces (APIs) (World Wide Web Consortium, 2009). Using ARIA live region markup it is possible to set the priority with which ATs should treat updates to the live regions.

Discussion

The preceding discussion outlines the move towards a more inclusive approach to the design of e-learning curricula and describes an accessible 3D virtual learning environment under development that has been designed in accordance with the principles of inclusive design. Preliminary testing of the 3D virtual learning environment was undertaken by Media Access Australia (Hollier, 2010) and as reported by Wood (2010a), these trials identified significant issues with the Web 2.0 integration prior to the implementation of the WAI-ARIA solution. These issues were addressed using live region mark-up as described in the previous section.

There are, however, further areas of development required to ensure the 3D virtual learning environment and Web 2.0 application are fully compliant with W3C WCAG 2.0, IMS and UDL guidelines. Some of the remaining challenges include the need for a solution that enables live captioning during verbal presentations in the virtual world (at present this is managed using either a prepared note card that is displayed as the speaker presents or through the aid of a live captioner), the difficulty of ensuring that users who are creating new content label their objects so that the information is available for the audio output and similarly, ensuring that users provide streaming captions for video content, and transcripts for audio streams.

Another remaining challenge concerns the Web 2.0 solution, which is designed to provide flexibility for users who are unable to log into the 3D virtual world when away from their computer and for users with low end devices, which are unable to render 3D graphics. Despite t ambitions, this alternative does not provide the same sensory experience as participating in the virtual world using the 3D viewer. With an estimated 4.6 billion mobile telephone subscriptions globally and mobile broadband subscriptions now overtaking fixed broadband subscribers (The world in 2009: ICT facts and figures, 2009), “low-threshold” and “light weight” accessible communications with 3D Virtual Worlds will become increasingly important.

Conclusion

Our research has identified the affordances of Web 2.0 and 3D virtual learning environments for students with disabilities, as well as the potential of such environments for providing flexible and engaging simulated learning environments. The research described in this paper demonstrates the challenges in ensuring that new and emerging e-learning technologies such as these are accessible to a diverse student population. A brief overview of relevant guidelines based on the principles of inclusive design aimed at supporting teachers and developers of e-learning curricula is also provided. The design and development of an accessible Web 2.0 application and a 3D Virtual World environment is discussed as an example of how these principles can be applied to highly visual and multimedia rich learning technologies. The preliminary testing of this environment highlighted the accessibility issues associated with AJAX and also led us to adopt the WAI-ARIA protocol to address those issues. While our focus has been on the use of the Web 2.0 application as a “low-threshold”, interface to 3D virtual learning environments, the findings from our research into the accessibility challenges associated with AJAX and dynamic websites also provide valuable insight into the solutions required to ensure that Web 2.0 technologies employed for a range of applications (for example social networking sites) are more accessible for users with disabilities.

The next stage of our research will be to address the accessibility concerns reported by Media Access Australia (Hollier, 2010) prior to undertaking more rigorous accessibility and usability testing with people who have disabilities. Further developments will include improved access via mobile phone devices, incorporating a content management system to provide a more user friendly system for those presenting or conducting sessions in 3D virtual worlds and the preparation of detailed accessibility guidelines for teachers designing e-learning curricula for these kinds of environments and for the developers of Web 2.0 and 3D virtual worlds. The 3D virtual learning environment will be trialled in several mainstream and special schools in rural areas of South Africa and Sub-Saharan Africa throughout 2011 and 2012. Our work in developing countries to date has already highlighted the need for more robust, low cost, low-threshold accessible communication technology solutions capable of running these rich media environments

Both Gibson (2007) and Zajiceck (2007) note that these technologies rely on a commitment by the users themselves to creating accessible content. This remains one of the greatest challenges in the design of inclusive e-learning environments that facilitate creativity, construction and collaboration to accommodate “Generation C” (Bruns, 2008) learners. However, the research reported in this paper shows that there are already solutions in place and under development, many of which have been designed by users who have collectively created solutions to the accessibility challenges they have encountered. As we await future developments of a more intelligent Web 3.0 we need to also harness the power of the participatory Web to encourage the users themselves to contribute to emerging solutions aimed at creating a more universal and inclusive e-learning world for our students.

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