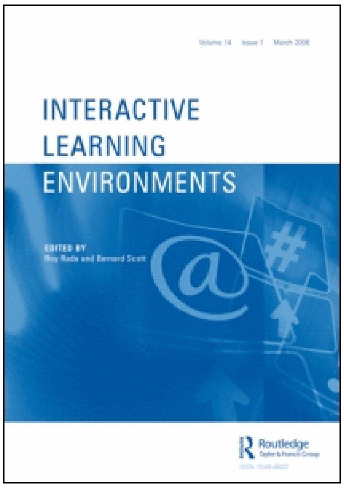

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Brave new (interactive) worlds: A review of the design affordances and constraints of two 3D virtual worlds as interactive learning environments

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Brave New (Interactive) Worlds: A review of the design affordances and constraints of two 3D virtual worlds as interactive learning environments

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Three-dimensional virtual worlds are an emerging medium currently being used in both traditional classrooms and for distance education. Three-dimensional (3D) virtual worlds are a combination of desk-top interactive Virtual Reality within a chat environment. This analysis provides an overview of Active Worlds Educational Universe and Adobe Atmosphere and the pedagogical affordances and constraints of the inscription tools, discourse tools, experiential tools, and resource tools of each application. The purpose of this review is to discuss the implications of using each application for educational initiatives by exploring how the various design features of each may support and enhance the design of interactive learning environments.

During the past decade the Internet and the World Wide Web have impacted greatly the field of education. These technology infrastructures have generated and supported an abundance of emerging technologies which support interactive learning. Among the various emerging technologies are networked, three-dimensional virtual worlds. Three-dimensional (3D) virtual worlds can be characterized as desktop interactive Virtual Reality within a chat environment. Three-dimensional virtual world applications come with varying features, however, typically most provide three main components: the illusion of 3D space, avatars that serve as the visual representation of users, and an interactive chat environment for users to communicate with one another. Several of the more popular 3D virtual world applications include Active Worlds, OnLive! Traveler, There, and Adobe Atmosphere.

Although 3D virtual worlds are relatively new, there has been research conducted as well as a variety of educational initiatives incorporating 3D virtual environments as both a supplement to traditional classroom activities (Bailey & Moar, 2001, 2002; Barab, et al., 2000; Barab, Hay, Barnett & Squire, 2001; Bers, 1999; Bers & Cassell, 1999; Corbit & DeVarco, 2000; Dickey, 2003, 2004, in press). Barab et al. used

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virtual worlds as a support in fostering undergraduate students' understanding of astronomy within a constructivist-based participatory learning environment. Barab et al. and Barab, Hay, Barnett & Squire found that virtual worlds can be used effectively as a tool to foster rich understandings of astronomical phenomena. Bers and Cassell (1999) created a virtual world setting within a constructivist paradigm to study how children construct identity and the role of storytelling in identity construction. Bailey and Moar used the Vertex project to explored the use of virtual worlds within a constructivist paradigm and found that virtual worlds fostered collaboration, communication, and storytelling with 9–11 year old students. Dickey's (2003, in press) research into educational initiatives developed within communities of 3D virtual worlds revealed that 3D virtual world applications such as Active Worlds support a constructivist perspective by affording real-time communication along with a visual environment and resources to support collaboration. The use of the 3D virtual world setting also helped support the course objectives by providing a setting for students to apply their skills in a collaborative multidimensional environment (Dickey, 2004).

There have been various educational initiatives in virtual worlds. Corbit and DeVarco (2000), both long-term researchers and practitioners working both independently and collaboratively on such projects have created a virtual high school, a virtual science centre, and more recently hosted a virtual conference for educators and researchers using virtual environments for teaching and learning. Virtual Reality theorist and practitioner Heim (1999) has used a variety of virtual world applications to serve as both a supplementary and primary medium for his classes in virtual world design at the Art Center College of Design. Additionally, Heim (2001) has used various 3D virtual world applications to serve as the primary medium for invited discussions about the nature of cyberspace. Three-dimensional virtual worlds have also served as a medium for both synchronous and asynchronous distance learning. For example, Monarchi used a 3D virtual world setting for an undergraduate course in business computing (Dickey, 2000, 2004, in press).

Although relatively little research has been conducted about the use of virtual worlds for learning, much of the existing research about the educational use of predecessor technologies such as text-based virtual worlds (e.g., MOOs and MUDs) and Virtual Reality is situated within a constructivist paradigm of learning (Bricken & Byrne, 1993; Bruckman, 1997; Dede, 1995; Riner, 1996; Winn, 1997). Research from the educational use of immersive Virtual Reality (VR) provides compelling evidence of the potential that graphically rich three-dimensional settings provide for constructivist learning activities (Bricken, 1990, 1991; Bricken & Byrne, 1993; Dede, 1995; Dede, Salzman, & Loftin, 1996; Winn, 1993, 1997). One of the main advantages of VR is that the learners are able to view an object or setting from multiple perspectives (Bricken, 1990; Dede, et al. 1996). Dede's (1995) investigations reveal that virtual environments offer many benefits such as provisions for experimentation without real world repercussions, opportunities to "learn by doing", and the ability to personalize an environment. Similarly, Bricken and Byrne noted that VR affords learners opportunities to learn by interacting with virtual objects, which depending upon content, may lead to better conceptual understanding of the content. This is in part due to the transparent interface that VR affords (Bricken, 1991). Winn (1993) argues that it is this transparency of knowledge representation that allows learners to approach some concepts as first-person non-symbolic experiences, whereas too often information is codified and represented as "third-person symbolic experiences". According to Winn (1993), virtual environments can help bridge the gap between experiential learning and information representation.

There has been much support for the integration of interactive Virtual Reality (VR) technology in education (Bricken & Byrne, 1993; Byrne, 1996; Osberg, 1997; Winn, 1993, 1997). However, one of the strongest arguments against the use of VR for education is that the software and equipment are costly and required technical expertise and skills beyond that of most K-12 and even higher education teachers (Winn, 2002). In order for educators to adopt and integrate a technology, it must be accessible both in terms of cost and technical skills required (for both teachers and students). Despite the limitations of traditional VR, there is now an ever-growing selection of commercial 3D virtual world applications available for educators. These 3D applications offer many of the same advantages of immersive VR (interactive 3D environments), but are less costly. Unlike traditional VR, 3D virtual world applications are networked, allowing users to interact with both the environment and with other users. Most 3D virtual world applications provide core features such as the illusion of 3D space, avatars that serve as visual representations of users, and an interactive chat environment. However, each application has various strengths and weaknesses in design and it is important that educators and instructional designers have knowledge of how these features are manifested in order to make informed choices when selecting a 3D virtual world application to serve as an interactive learning environment. The purpose of this paper is to provide a review of the pedagogical affordances and constraints of two interactive 3D virtual world applications (Active Worlds and Adobe Atmosphere). Specifically this review provides (a) an overview of the interface of the two applications; (b) a review of design affordances and constraints of the types of tools necessary to support a constructivist learning perspective (i.e., inscription tools, experiential tools, discourse tools and resource tools); (c) a conjectural analysis of the educational implications of each application; and (d) a summary comparison of design features of both applications.

Theoretical Framework

The current wave within the field of instructional design is the cultivation of interactive learning environments (Hannafin, Hall, Land, & Hill, 1994; Hannafin, Land, & Oliver, 1999; Jonassen, 1999; Land & Hannifin, 1996, 1997; Winn, 2002). The emergence of learning environments has been in part fueled by the epistemological shift towards constructivism. Central to a constructivist theoretical perspective is the belief that knowledge is constructed, not transmitted, and that learners play an active role in the learning process (Duffy & Cunningham, 1996; Johnson & Johnson, 1996; Jonassen, 1999). The central focus or activity within a learning environment is often some form of problem-based or project-based learning. To foster the construction of knowledge, learners should have opportunities for exploration and manipulation within the learning environment (Cognition and Technology Group at Vanderbilt, 1993; Jonassen, 1992). One common characteristic of technology enhanced learning environments is inscription systems, which allow learners to ''externalize understanding'' (Winn, 2002). Inscription systems may take the form of cognitive tools such as datasets, models, images, as well as multiple modal tools that allow learners to construct external representations (Winn, 2002). Technology enhanced learning environments also typically provide access to resources, models, exemplars, and information gathering tools (Jonassen, 1999). Models and exemplars foster the development of problem-solving skills while ''just-in-time'' resources and information gathering tools enable learners to access relevant and appropriate information quickly (Jonassen, 1999; Jonassen, Peck, & Wilson, 1999). Another critical asset learning environments should also include is discourse opportunities between learners. Conversation and discourse fosters collaboration and supports social negotiation in learning (Jonassen, 1999; Lave & Wenger, 1991; Vygotsky, 1978). This in turn allows learners to share information, test understandings, and reflect on learning (Duffy & Cunningham, 1996; Jonassen, 1999). This epistemological orientation illustrated in the design of learning environments is well situated within the constructivist perspective of learning. The theoretical assumption is that learners construct understandings by interacting with information, tools, and materials as well as by collaborating with other learners.

Overview

The two applications presented in this review are Active Worlds and Adobe Atmosphere. The purpose for selecting these two applications is because both are free browsers/players which may be easily downloaded and both have a history of supporting educational initiatives. The following consists of a discussion of the various tools which support the design of interactive learning environments (i.e. inscription tools/systems, discourse tools, experiential tools, and resource tools) along with the educational implications and a comparison of both applications.

Active Worlds Educational University

Active Worlds™ is one of the oldest and most dynamic 3D virtual world applications online today. The client-server application consists of the Active Worlds universe with hundreds of individual worlds for users to explore and to communicate with other users worldwide. In 1999, the owners of Active Worlds created a separate universe devoted solely to educational initiatives called Active Worlds Educational Universe (AWEDU).

Interface. The AWEDU browser interface is comprised of three main windows as shown in Figure 1. The centre and most visually prominent window is the 3D world

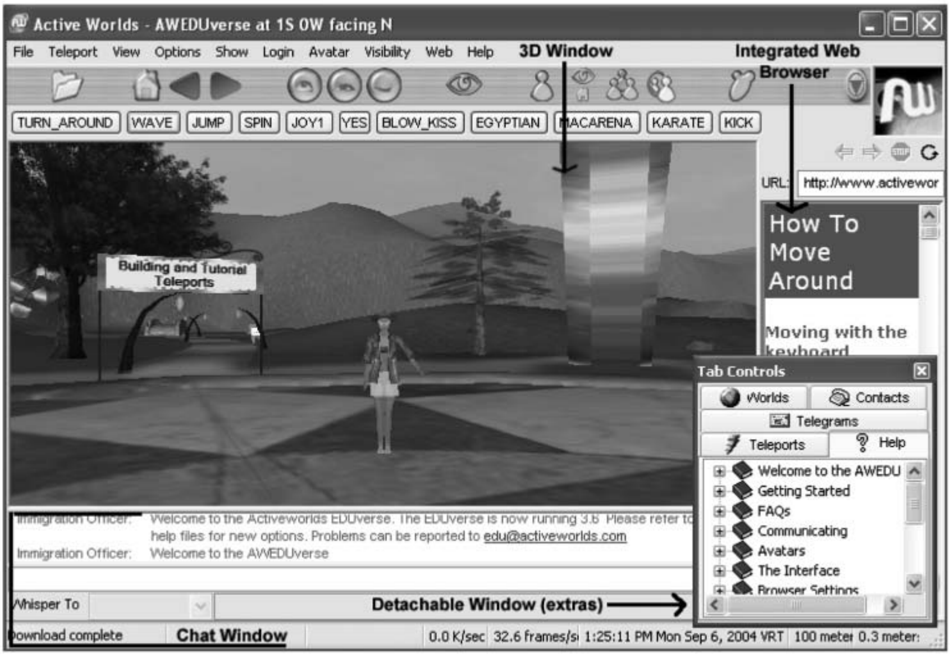

Figure 1. The Active Worlds Educational Universe Browser.

view in which users interact with other users and the environment and navigate through a world. Beneath the 3D window is a chat dialogue box for communication. To the right is an integrated Web browser that allows users to interact both within the 3D environment and with Web pages. Additionally users may opt to activate a detachable tabbed window that allows for a variety of extra functions for navigation, communication, and help.

Within the AWEDU environment, users are represented by both their self-selected unique identity (i.e., alias or nickname) and by their avatar. An avatar serves as the visual representation of users currently inhabiting a particular world. Upon entering a world, users may select from a library of avatars offered by that world. Avatars serve not only as the visual representation of a user, but also as the "camera" or viewpoint into the 3D environment.

Inscription tools: Building worlds and environments. The AWEDU environment, which is restricted to educational initiatives, provides resources to enable even novices in 3D development to quickly construct and customize a 3D virtual world. Multiple users (students and educators) can work simultaneously or separately to build within an environment. AWEDU provides access to libraries of hundreds of objects ranging from building items such as terrain, trees, walls, floors, and doors to household objects such as tables, chairs, and beds. Educators who own worlds can download objects to be used in individual worlds. Objects may be added, copied, deleted, rotated, moved, rolled, and tilted through the objects' properties dialogue box. This dialogue box may be activated by right-clicking on an object (see Figure 2).

Additionally, world owners and builders (students) may create interactive events within the environment by adding sensors that trigger actions either within the 3D environment and/or activate the integrated Web browser to load a specified page. For example, an object may become animated (such as a door opening) when a user's avatar bumps into it or clicks on it. Several actions may be specified such as, for example, a sound file of a fire may begin to play as a user's avatar approaches an animated fire. Actions are specified in the *Actions* field of the object properties box. World owners also may add sound to a world. Sound files may also be attached to a specific object and music or background sounds may be attached to a particular part of the environment.

World owners have options of both creating and limiting access to their world, thereby insuring privacy and security in the learning environment. Within the 3D environment, world owners can assign or deny users/learners the option of building within the world. This enables learners the opportunity to add to the environment. World owners have a great deal of control over how to customize their world. They control the ground and sky, lighting and water. They may designate gravity and whether user's avatars will be limited to real world conventions or be allowed to fly and move through objects.

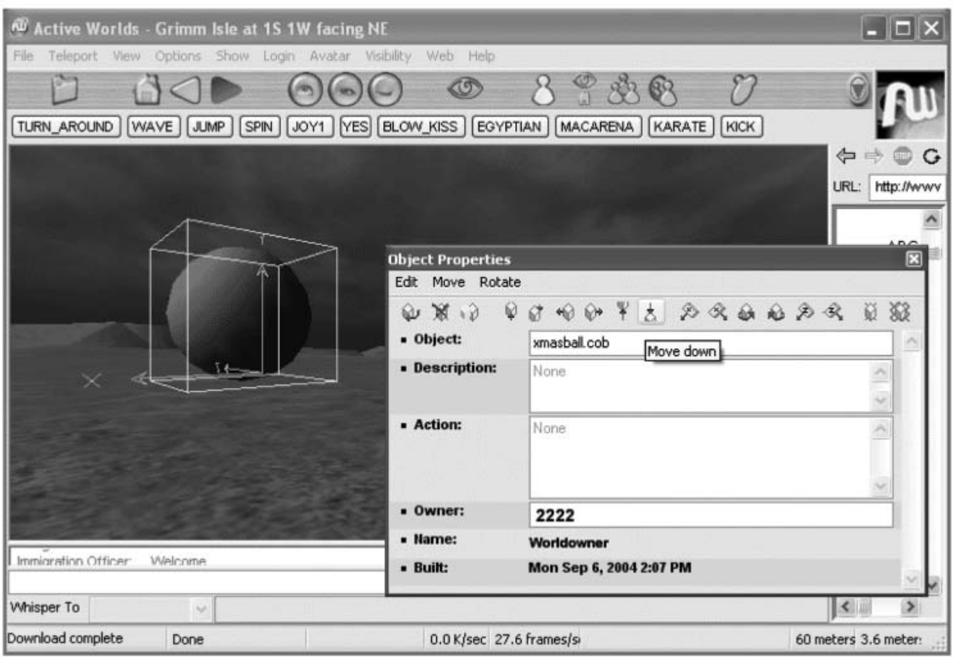

Figure 2. The Objects Properties dialogue box.

Although the AWEDU libraries contain thousands of objects, educators may wish to create unique objects. There are no 3D object modellers provided by AWEDU. Special pricing is available for some versions of Caligari's Truespace; however, users must be skilled in 3D object modelling and surfacing or be willing to invest the time and resources to learn in order to create original objects.

Discourse tools. Upon entering the AWEDU universe, users may self-select a unique identity. No other user within the universe may use this identity. A unique identity helps establish both trust and accountability (Dickey, 2003; Jakobsson, 2001). Communication within the AWEDU environment is limited to text-chat. Upon first speaking or chatting within a world, a user's name appears above his/her avatar's head. This allows users to recognize one another in the 3D environment. Chat text appears both in the text-dialogue box located beneath the 3D window, and it also appears above a user's avatar in the 3D window. Users may also establish contact lists of other users. A contact list allows users to find and communicate with each other in various worlds. Users also have the option of whispering to one another if their avatars are in close proximity or they may choose to send a telegram to another user who is visiting another world.

Experiential tools. As previously stated, users are represented in the 3D environment in the form of an avatar. World owners have the option of choosing a selection of avatars from a library provided by AWEDU. Because there is often a limited selection of avatars, many users may use the same avatar making it impossible to recognize a user based on just the appearance of his/her avatar. It is possible to create unique avatars, but the process requires a degree of expertise in 3D modelling, surfacing, and animation.

Users can control their avatar to move through the 3D environment by moving, walking, and sliding, and by flying and ascending. Users have the choice of toggling between perspectives by viewing the environment from first-person (through the eyes of their avatar) and from third-person (orthographic). When an avatar encounters a solid object (e.g. a wall of a building) the avatar will register a slight impact and be prevented from moving through the wall. As previously stated, world owners and builders may also adorn an environment with sensors and triggers. As a learner's avatar encounters a sensor or trigger, a variety of pre-specified actions may occur such as being transported to a new location or world, activating a sound file and animation, or even activating a Web page to load in the integrated Web browser.

There are many opportunities for learner exploration within the AWEDU environment. Learners may move through the environment encountering other learners and objects. However, opportunities for manipulation are still fairly limited. Other than navigation, learners have little control over their avatar's body. For example, it is not possible to pick up an object.

Resource tools. Learning resources may come in a variety of media, however, often text or access to text is a common form. With the exception of large signs and billboards, it is difficult to read text within the 3D environment; however, the AW browser has an integrated Web browser built into the AW application. Sensors and triggers may be placed in the 3D environment and when users encounter a sensor (bump into or click on a designated object) the integrated Web browser may automatically load a specific Web page or research.

Educational implications. There have been many educational initiatives within the AWEDU universe ranging from informal training for new users, to using AWEDU as a distance education medium for university level courses (Bailey & Moar, 2001, 2002; Corbit & DeVarco, 2000; Dickey, 2003, 2004, in press; Heim, 1999, 2001). AWEDU affords many of the pedagogical affordances for creating constructivist-based interactive learning environment, however, with constraints. The inscription tools allow world owners and designated users (learners) the opportunity to create and build. This is important because inscription systems, allow learners to "externalize understanding" (Winn, 2002). Both Heim's (1999) work with university students and Bailey and Moar's (2001) work with primary school children used the inscription tools of AWEDU to allow students to externalize understanding through building environments. However, one constraint is the lack of a modelling system to allow students to quickly and easily build custom-made objects.

Within a constructivist-based interactive learning environment, learners should have opportunities for exploration and manipulation within the environment (Cognition and Technology Group at Vanderbilt, 1993; Jonassen, 1992). AWEDU affords learners opportunities for exploring the environment by allowing them to move in all directions. The experiential tools along with the inscription tools allow learners to explore unique environments not easily replicated in a traditional classroom setting (Bailey & Moar, 2001, 2002; Heim, 1999). However, the experiential tools are not without constraints. Users cannot pick up objects and examine them. Additionally there is very little control over kinesthetic experiences. Likely this is not an application suited for some areas of study in which kinesthetic experiences are part of the learning process.

One area that deserves closer scrutiny is how AWEDU might be intended for use. The discourse tools support synchronous communication, however, communication is limited to text and not audio. Conversation and discourse foster collaboration and supports social negotiation in learning (Jonassen, 1999; Lave & Wenger, 1991; Vygotsky, 1978). However, the constraints of the discourse tools indicate that AWEDU may not be suitable as the primary medium for a lecture/discussion style class. Differences in typing skills may disadvantage some students. Additionally, differences in written language skills might also serve as an impediment for other students. In a traditional classroom differences in communication skills advantage some students over others, however, a traditional classroom also offers a wider range of avenues for non-verbal communication. Although there is indication that AWEDU does offer a degree of embodiment within the design, it does not allow for the variety and complexity of non-verbal communication that is available in a face-to-face setting.

Adobe Atmosphere

In 2001 Adobe launched Adobe® Atmosphere™, a tool for 3D virtual world authoring and interacting. Atmosphere allows educators, instructional designers, and students to create immersive desktop interactive environments integrating graphics, video, and audio in a 3D environment. Worlds can be linked to each world to maintain continuity in the immersive experience.

Interface. Atmosphere Player is an embedded plug-in for Web browsers and documents. The browser window becomes the 3D interactive environment with five additional pop-up windows. One pop-up window allows users to select avatars or list the URL for their custom-made avatar and a second window allow users to perform basic controls on their avatar if the avatar has that availability. Another window allows users to identify other users simultaneously visiting a world. There is also a chat window which allows users to chat with others currently visiting the same world. Finally, there is a window allowing users to select various preferences (see Figure 3). The control icons at the bottom of the browser activate the individual windows.

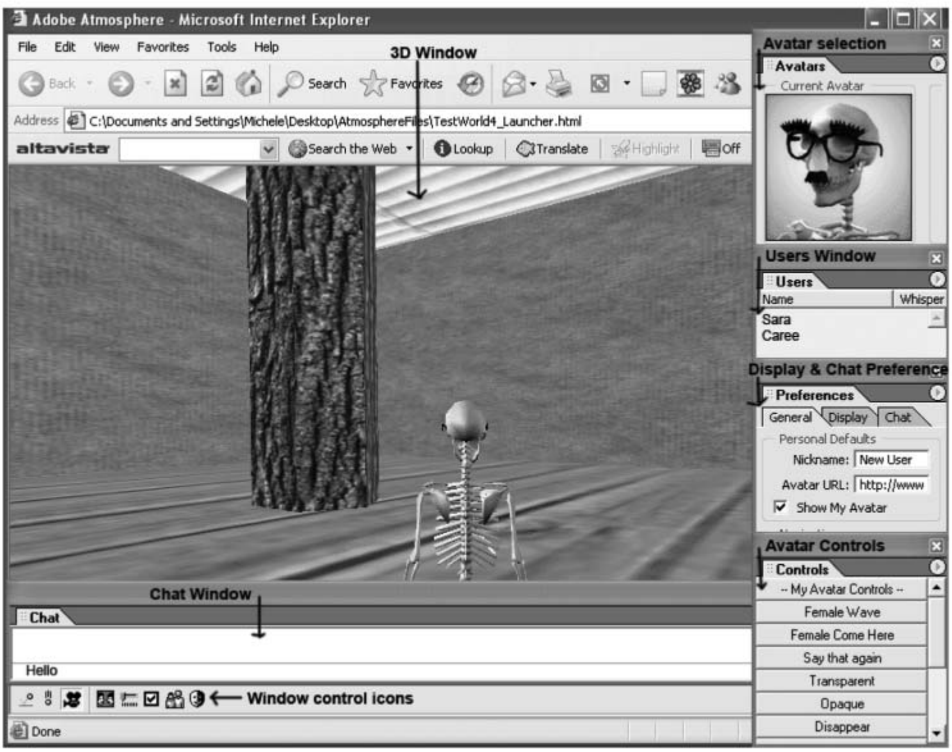

Figure 3. The Adobe Atmosphere Player embedded plug-in.

Inscription tools: Building worlds and environments. Adobe Atmosphere offers much potential for developing unique environments for learning. Adobe Atmosphere allows novice 3D developers (and educators) means to create compelling 3D environments. The interface is intuitive for users familiar with 3D software and likely novices would not find it difficult to become acclimated quickly to the interface. Adobe Atmosphere provides a selection of predefined basic geometric objects such as floors, walls, cubes, cones, and so forth for builders to combine, manipulate, and customize to form objects in the environment (see Figure 4). For more sophisticated environments, Atmosphere allows developers to designate lighting controls, import and add textures to objects, add sound, and create interactive opportunities by embedding JavaScript commands to objects within the environment. Developers can also provide options which allow users to pick-up objects in the 3D environment and manipulate them. Additionally, individual objects within the 3D environment can be linked to Web pages, allowing users to view text and image information supplemental to the 3D environment. Unlike Active Worlds, Atmosphere worlds have edges and limits; however, developers may also embed portals within a world so a user may move seamlessly between worlds. Extensibility options are somewhat limited with Atmosphere. Students wishing to add to an environment would have to have a copy of the Atmosphere file – which also limits several students simultaneously working on the

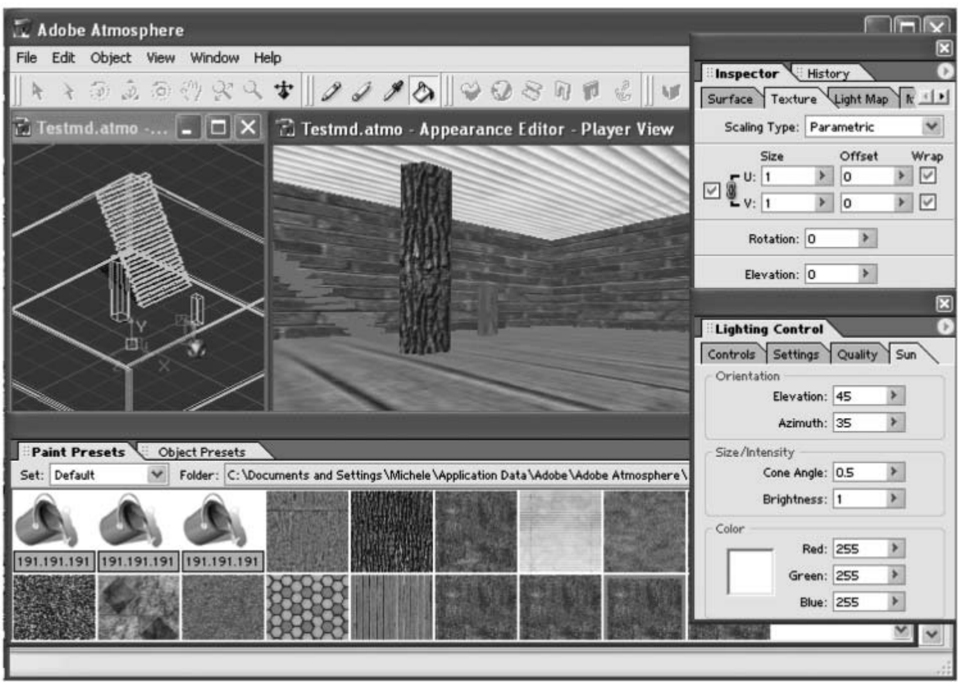

Figure 4. The Adobe Atmosphere interface.

same environment. However, students would have the availability of creating their own world.

Discourse tools. Communication within the Atmosphere environment is text-based chat. Worlds may be chat enabled or disabled. Because worlds are not centrally hosted, users do not have the availability of using unique identities. On one hand this allows users more flexibility in representation, yet on the other hand, it decreases user accountability and trust. There are no contact lists such as those afforded by AWEDU or provisions for contacting users currently visiting other worlds; however, there are options for whispering to users currently visiting the same worlds.

Experiential tools. Users in an Atmosphere environment are free to represent themselves as they choose. Because Atmosphere worlds are not centrally hosted, but rather worlds are hosted on individual servers, a user can create and use her/his custom-made avatar by having the avatar stored on a Web server. Within the Atmosphere Player interface, a user can designate the URL of the avatar. This in turn allows users to both control their visual representation and to be recognized within an environment based upon that visual representation. Unlike AWEDU, a user may be recognized based on the appearance of his/her avatar. However, it is interesting to note that in order to determine the identification of individual avatars users must look in the tabbed window called *Users*. The *Users* window lists all of the users currently inhabiting a world and a small image of their corresponding avatars (see Figure 4).

Like AWEDU, Atmosphere users may move along the X and Z axis. Unlike AWEDU, users may specify whether to activate collision rather than the world's owners controlling that option. Users cannot control moving along the Y axis, but they may activate the gravity option which allows an avatar to float above the surface of the ground. Unlike AWEDU, if designated, users can manipulate objects in the 3D environment. This provides more levels in interactivity in the 3D environment. Objects manipulated by one user can be viewed by others. This provides educators and students with the opportunity to demonstrate techniques.

Resource tools. Because Atmosphere Player is a Web plug-in, developers may easily create worlds which are embedded within Web pages. This allows for the seamless integration of text-based resources. Additionally, it is possible to create links within the 3D environment to Web pages. This would enable learners quickly to access text-based resources as well as other forms of media.

Educational implications. Although Atmosphere is a relatively new application, it has already generated educational initiatives ranging from use in classes exploring the design of 3D environments (Heim, 2001) to providing a medium for collaborative projects for NASA (Damer, 2004). It offers much potential as a medium for interactive and distance learning, particularly for intimate environments requiring less space. Atmosphere provides many of the pedagogical affordances for creating constructivist-based interactive learning environments; however, it also has constraints. The inscription tools allow learners the opportunity to create and build environments or representations which is important in a constructivist-based interactive learning environment for externalizing and representing knowledge (Winn, 2002). Although the modeller affords ample opportunity for creating custom-made objects, the process of creating objects (and environments) is time-consuming and requires some basic knowledge of 3D object modelling and surfacing.

Atmosphere provides discourse tools in the form of a text-chat tool. As previously stated, within a constructivist-based interactive learning environment, discourse tools foster collaboration and allow learners to share information, test understandings, and reflect on learning (Duffy & Cunningham, 1996; Jonassen, 1999). However, the lack of unique identities in Atmosphere is a constraint which may limit its suitability for some educational initiatives. Like AWEDU, this environment may not be well suited for lecture-styled classes due to the reliance on the text-based chat tool. One feature particularly important for educational use that Atmosphere experiential tools provide is the ability for users to create their own avatars. Within a constructivist learning environment, the ability to take on other roles and in turn develop multiple perspectives enhances the learning process (Johnson & Johnson, 1996). One of the goals of a constructivist learning environment is to find activities that support "dialogical interchange and reflexivity" (Duffy & Cunningham). Allowing users to self-define their representation in the 3D environments affords potential learners opportunities to try new roles and perspectives.

Summary Comparison

It is important to acknowledge that within a constructivist paradigm of learning, technology tools do not evoke the dynamics of a learning community, but rather these dynamics are the result of the interplay between content, the instructor, and the learners. Although, the affordances of tools may influence opportunities for discourse and interaction, virtual worlds are another tool for teaching and learning.

Inscription Tools

Out of the two applications, Active Worlds Educational Universe provides the easiest methods for creating and maintaining individual worlds. The pre-fabricated objects allow users to merely select and place objects. While customizing objects is limited, users may still add unique and animated textures. Interactive opportunities are also to some degree limited to a pre-defined choice of options, however, they are easy to employ and add to an object or environment. Atmosphere, on the other hand, allows for more diverse and unique environments. Because worlds are not centrally hosted, users are free to define their worlds in any way they choose. However, Atmosphere, while much easier to use than most 3D modelling programs, still requires developers to create most objects from combining and manipulating pre-defined geometric primitives (e.g. sphere, cube, tube, etc.). While this is not difficult, it does require a greater investment of time and energy. More interactive opportunities are also possible with Atmosphere; however, it does require developers to have some knowledge of JavaScript. The result of creating a world with Atmosphere is a world that is a more uniquely customized, but there is a greater investment in the design and development (see Table 1).

Discourse Tools

Both AWEDU and Atmosphere rely upon text-based chat. As previously stated, communication is dependent to a large degree upon typing skills and speed. Although the text-based chat windows of both applications support communication, the chat window tends to draw the user's attention away from the 3D environment. Within AWEDU, users have the option of allowing each user's name to appear above their avatar. This allows users to identify quickly other users in the 3D environment. Atmosphere does not have that option.

Atmosphere allows users to create, change, and alter their identities. While AWEDU also allows for changing identities, a user cannot use the same name as

Table 1. Comparison of tools.

		AWEDU	Adobe Atmosphere
Inscription tools			
	Library of objects	X	
	Modeller		X
	Interactivity	X	X
Discourse tools	Text-chat	X	X
	Audio-chat		
	Unique identities	X	
	Contact lists	X	X
	Whisper	X	X
	Telegrams	X	
Experiential tools			
	Avatar library	X	X
	Custom-made avatars		X
	Movement through 3D space	X	X
	Gravity	X	X
	Collision	X	X
	User specified gravity and collision		X
	Object manipulation		X
Resources tools			
	Integrated Web browser	X	X
	Seamless integration of Web browser	X	

another user. This prevents one user from impersonating another. The provisions of providing contact lists and maintaining unique identities affords the development of trust among users and accountability within the environment (see Table 1).

Experiential Tools

Both applications in this review represent a range of user visual representation. AWEDU is the most restrictive with users being limited to a choice of pre-selected avatars. Atmosphere affords users the greatest flexibility in the 3D environment because they are free to construct their own representation; however, this process requires an investment of time and resources. Depending upon the educational initiative, this may not be an investment learners or educators wish to allocate resources towards. Avatars may be created using Atmosphere Builder or with third-party software such as Curious Labs' Avatar Builder, but as previously stated, this also requires an investment of time and resources (see Table 1).

Both applications allow users a range of movement. In AWEDU, the world owners set preferences such as gravity and collision, thereby controlling the user's experience. In Atmosphere, gravity and collision are controlled by individual users. One additional option provided in Atmosphere is the ability to create objects, which may be manipulated by users in the 3D environments. This provision provides educators with more options for interactivity within the learning environment.

Resource Tools

Both applications provide opportunities of linking content in the 3D environment to Web-based resources. Atmosphere allows educators, designers, and students to embed the 3D environment within a Web page, possibly allowing users a seamless integration between Web resources and the 3D environments, however, creating links to Web-based resources is much easier to create and change with AWEDU environments (see Table 1).

Discussion and Conclusion

The purpose of this paper is to provide a review of two interactive 3D virtual world applications (Active Worlds and Adobe Atmosphere) by examining the affordances and constraints of the types of tools necessary to support a constructivist learning perspective (i.e., inscription tools, experiential tools, discourse tools, and resource tools). The goal of this investigation is twofold: the first is to inform educators and instructional design of the potential of 3D virtual worlds to support interactive learning environments and to provide an overview of two of the more popular applications. The findings of this analysis reveal that both applications provide a variety of tools to support a constructivist-based interactive learning environment, but each application has unique affordances and constraints which might determine the pragmatics of using each application. While some of the findings of this investigation reveal varying affordances and constraints of the design of the two applications, it is important to note that this investigation was limited to two virtual world applications. The scope of this analysis is by no means comprehensive, but rather intended to examine the pedagogical affordances and constraints of the discourse, inscription, experiential, and resource tools of Active Worlds and Adobe Atmosphere. The focus of this investigation is on the pedagogical implications of the affordances and constraints of these tools and not on effective means for using them. The findings of this study are not a prescription of how these applications should be used, rather the findings of this analysis are meant to serve as a guide and a point of departure about how the affordances and constraints of tools might support constructivist-based interactive learning environments.

Both 3D interactive virtual worlds provide various design affordances and constraints. According to Winn (2002), inscription systems which allow learners "externalize understanding" offer the greatest support for user-extensibility. AWEDU allows for the easy construction of worlds and environments by supplying a library of existing objects and textures. Learners can participate easily in simultaneously or separately adding and building within a world. However, Atmosphere allows users more customized control in building unique objects and environments. Both support constructivist inscription systems and would allow learners to externalize understandings by building within and adding to an environment, but the target learners and purpose of the learning environment should impact the choice. Similarly, learners should have opportunities for exploration and manipulation within the learning environment (Cognition and Technology Group at Vanderbilt, 1993; Jonassen, 1992). Both applications provide experiential tools in the form of avatars which allow users to interact in the 3D environment, however, avatar use in AWEDU is more restricted in terms of visual representation and with the manipulation of objects.

A critical asset in learning environments is support for discourse opportunities between learners. Theorists argue that conversation and discourse fosters collaboration and supports social negotiation in learning (Jonassen, 1999; Lave & Wenger, 1991; Vygotsky, 1978). Both applications offer discourse tools, however, the focus is different for each. With AWEDU, trust and accountability are valued assets in the construction of community, so unique identities are supported. There are no provisions for unique identities, so identity may be more fluid allowing learners to experiment with identity and representation.

Overall, Atmosphere is best suited for small, contained environments in which manipulation is desired beyond community and exploration. AWEDU is best suited to larger-scale environments in which community building and support is of primary importance for the learning environment. It should be noted that this review is neither comprehensive nor exhaustive. The educational context and purpose should determine the selection of an appropriate 3D virtual world application. Both applications presented in this review afford varying strengths and weaknesses for educators. The integration of a 3D virtual world offers innovative and unique educational opportunities for the support of interactive learning environments.

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