Recent Advances in Immersive Virtual Worlds for Education

Otto Borchert, Aaron Bergstrom, Jill Hockemeyer, Jeffrey Clark, Paul Juell, Phil McClean, Bernhardt Saini-Eidukat, Donald P. Schwert, Brian M. Slator, Alan R. White, Curt Hill, John Bauer, Francis Larson, Brad Vender, Bryan Bandli, Bing Chen, Michelle Dean, Richard Frovarp, Guy Hokanson, Christina Johnson, Jeff Kittleson, Ned Kruger, James Landrum, Mei Li, Benjamin Nichols, John Opgrande, Rebecca Potter, Patrick Regan, Lai Ong Teo, Anurag Tokhi, Shannon Tomac, Joy Turnbull, Jane Willenbring, Qiang Xiao, Xinhai Ye, Melissa Zuroff
World Wide Web Instructional Committee
North Dakota State University
Contact Person: Otto_Borchert@ndsu.nodak.edu

Abstract

The World Wide Web Instructional Committee (WWWIC) at North Dakota State University (NDSU) is in the process of developing interactive and immersive worlds for educational purposes. WWWIC's major projects include the Virtual Cell for cell biology education, the Geology Explorer for geology education, and the Digital Archive Network for Anthropology for archaeology and anthropology education. This paper will highlight recent experimentation results, the major components of each of these projects, and recent developments that have occurred to create more visually stimulating and educationally challenging worlds for educating students in the sciences.

Introduction

Over the past several years, the World Wide Web Instructional Committee (WWWIC) at North Dakota State University (NDSU) has built upon its previous successful developments in the area of web-based, interactive, immersive environments for education and research. These environments began with text-based technologies using a goal-driven, learn-by-doing, game-like approach to student learning (Slator et al., 1998). Although these techniques were found to be effective, WWWIC felt that further compelling visual enhancements could supplement project goals. Recent technologies that facilitate these enhancements are real-time, desktop graphics accelerators and broadband technologies such as Internet2, DSL, and cable modems. WWWIC's new vision uses visual enhancements to substantially increase the instructional depth of its immersive environments by incorporating realistic 3D (3-dimensional) and pseudo-3D graphics.

WWWIC is an ad hoc group of university faculty dedicated to developing internet-based education and research software. Members of this group foster cross-disciplinary, collaborative relationships with WWWIC faculty, students, and staff as well as those from other universities and institutions. The content of WWWIC immersive environment projects includes subject matter across a variety of disciplines such as anthropology, archaeology, cell biology, commerce, computer science, geology, and history. Three of these projects have begun to make use of the technological advancements described above, and will be discussed in this paper. These projects are Virtual Cell (an environment for cell biology education), Geology Explorer (an environment for geology education), and DANA (a Digital Archive Network for Anthropology).

The Virtual Cell project focuses on teaching undergraduate and high school level students the scientific methods used by researchers in the quest for knowledge about the structure and function of a biological cell. These techniques are conveyed to the student through the use of a computer generated, 3D immersive environment where by the student plays the role of a submarine-driving cell biologist roaming about the interior of a plant cell.

The Geology Explorer adds enhanced realism to instruction of the scientific methodology practiced in the field of geology. The immersive environment of Geology Explorer allows undergraduate and high school level students to freely explore an immersive, pseudo-3D planetary simulation. In this environment, the students are able to improve their ability to solve authentic problems regarding basic rocks and minerals. Recent additions to the project include the development of a graphical user interface, the addition of new learning modules, and the addition of more intelligent tutors to help in testing and learning.

Unlike the two previously mentioned projects, DANA (Digital Archive Network for Anthropology) is not an immersive educational environment. Rather, DANA is meant to be a set of globally accessible curation tools that will allow for the development of research and education freeware applications within the discipline of anthropology.

DANA is a prototype 3D model and multimedia storage system developed by the NDSU Archaeology Technologies Lab (ATL). In the future, DANA will leverage technologies developed by WWWIC in order to implement multi-user research environments for collaborative data analysis and Virtual Archaeology Labs. These labs will allow access to the world's wealth of archaeological artifacts as well as items and fossils used in both physical and cultural anthropology. This access will be available whether a student or researcher is located at small community college in the Midwest or a major university in India. In addition, DANA will allow museums to quickly generate digitally enhanced exhibits for simultaneous delivery of content to exhibit kiosks and web-portals extracted from their own collections as well as artifacts and objects from other museums whose collections are accessible through the network.

Teaching Principles

The purpose of teaching students has always been to prepare them for experiences in the real world. Professors have been attempting to provide this for many years in the form of lab experiences, field trips, or simple bookwork. Though many instructors currently wish to offer these experiences to their students, many find it impossible to do so. Field trips are often cumbersome to organize for very large groups of students, some learning environments are impossible to visit and explore, and at other times it is simply too expensive for students to go on a long expedition. For the past several years, WWWIC has been creating tools to allow virtual experiences via a web-based immersive environment.

These tools take the form of multi-user environments/games that offer students a role-playing experience in which they gain a more complete understanding of the material being presented. The experiences played out by the students are based on a series of goals that students must

obtain in order to advance to the next level. Once students begin playing, they seamlessly enter a virtual world to become scientists: performing experiments, interacting with the world and with each other, and learning how to apply the scientific method in a real-world situation. These worlds are referred to by WWWIC as Immersive Virtual Worlds (IVW). An IVW offers the student a characteristic learning environment guided by the nine principles of WWWIC research. These principles require that IVW's be game-like, spatially oriented, goal-orientated, immersive, role-based, exploratory, interactive, multi-user, and teach through learn-by-doing techniques (Slator et al., 1998).

WWWIC first constructed IVW's as text-based educational environments in an object-oriented multi-user domain server called Lambda MOO (Curtis, 1998). Data from these early environments showed that students could learn and retain knowledge more effectively through the use of IVW's than conventional teaching methods (Saini-Eidukat, Schwert, & Slator, 1999). As the Internet grew and connection speeds increased, WWWIC began a transition process to move its text-based IVW's toward GUI-based IVW's. Students are now offered more than just text. Technologies such as Java, Java3D, and VRML 97 (Virtual Reality Modeling Language) now allow students to consume visualizations of structures, objects and processes of interest that previously they were only able to imagine.

Data Results

The educational value of the WWWIC IVW's are measured using scenario-based questions that test the students' ability to think like a professional in a given field. These have been evaluated several times over the past four years. A 1998 study of Geology Explorer's educational value showed that students who played the game scored significantly higher on post test scenarios compared to students who took part in an alternative exercise or did no additional studying at all. A similar study was conducted using the Virtual Cell IVW in 1999. This study showed that students who had partaken in the Virtual Cell experience scored significantly higher on cell biology post test scenarios than students who had partaken in an alternative web exercise (McClean, Saini-Eidukat, Schwert, Slator, & White, 2001).

After students completed their respective assignments (i.e., Virtual Cell, web-based alternative, and textbook-based alternative) they completed an evaluation form about their experience in the study. Total scores and subscale scores were derived from the evaluation form that addressed issues such as 1) usability, 2) attitude, and 3) degree of challenge. The questions included in each of these three subscales were similar in content, but varied according to the aspects of the experience being evaluated. Students rated each question on a five-point scale (1=most optimal experience; 5=least optimal experience). Lower overall total scores and lower subscale scores indicate students viewed their experience with their assigned task as more positive. Sample comparisons for each subscale are listed below.

"Usability" example item
Virtual Cell: "The game was *difficult* versus *simple* to operate."
Web-based: "The answers were *difficult* versus simple to find."
Textbook-based: "The answers were *difficult* versus *simple* to find."

"Attitude" example item
Virtual Cell: "I *liked* versus *disliked* the concept of the game."
Web-based: "I *liked* versus *disliked* the concept of studying WWW sites and answering questions to learn."
Textbook-based: "I *liked* versus *disliked* the concept of studying the textbook and answering questions to learn."

"Degree of challenge" example item
Virtual Cell: "The game remained *surprising* versus became *predictable*."
Web-based: "The questions were *surprising* versus *predictable*."
Textbook-based: "The questions were *surprising* versus *predictable*."

Table 1: Mean scores from the Student Evaluation Form.

	Virtual Cell (*n*=136)	Web Assignment (*n*=177)	Text Assignment (*n*=160)
Mean total score (Score range = 13-65)	39.21_{ns}	36.13_{ns}	36.26_{ns}
"Usability" (7 items)	22.13_{ns}	20.84_{ns}	20.23_{ns}
"Attitude" (3 items)	8.86_{ns}	7.37_{ns}	8.01_{ns}
"Degree of challenge" (3 items)	8.23_{ns}	7.93_{ns}	8.03_{ns}

ns= not statistically significant

Table 1 shows a comparison among these assignment types for a 2000 Virtual Cell experiment. Among the three assignment types, no statistically significant differences were detected among the subscales.

This shows us that the students do not view the Virtual Cell experience any differently than other more traditional approaches when features such as usability and challenge are considered. Following completion of each type of assignment (i.e., virtual cell, web, and text) students took a standard multiple-choice exam in their general biology class. This exam was coordinated with the timeline of the study so the test material was similar in biology content (e.g., organelle identification and cellular respiration) to the topics covered in each assignment. A subset of questions from each topic area (i.e., organelle identification and the electron transport chain) was selected from the exam by two Ph.D. level biologists to serve as validation measures of student learning for these two important biological concepts. The performance among the three assignment types was not significantly different. Therefore, each of the three assignments has

equal benefit relative to the course material. But as was described in the above, only the Virtual Cell leads to significantly improved scenario question scores.

Table 2: Student exam performance.

	Virtual Cell (n=185)	Web Assignment (n=184)	Text Assignment (n=194)
Overall exam score (%)	58.01%$_{ns}$	59.03%$_{ns}$	59.44%$_{ns}$
Correct organelle questions (%)	63.24%$_{ns}$	66.44%$_{ns}$	67.01%$_{ns}$
Correct electron transport chain (%)	50.18%$_{ns}$	54.48%$_{ns}$	60.02%$_{ns}$

ns=not statistically significant

Virtual Cell

From the beginning, the goal of the Virtual Cell has been to create an interactive, multi-user, 3D environment in which students are actively engaged with the content and methodology of cell biology in a manner that is consistent with the nine principles of WWWIC research. To achieve this goal, in 1998 the Virtual Cell development group quickly adopted the VRML 97 standard for 3D model delivery via the Internet. At the time, the best solution for integrating a VRML scene into a Java applet was the CosmoPlayer VRML plug-in (Currently the CosmoPlayer plug-in is freely available for the PC platform from the Virtual Cell website at http://vcell.ndsu.edu/software.htm by permission of Computer Associates, Inc.). However, due to a rapidly changing industry dynamic, this soon became more of a hindrance than a facilitator in the group's Virtual Cell development plans.

The CosmoPlayer version currently operates in the following manner. The software contains 3D representations of components and organelles of a cell (nucleus, mitochondria, chloroplast, etc.). At the outset, the project's development group made a conscious decision to render the organelles as representational objects. This decision was made because members of the development group observed that when students are presented with a real-world image (e.g. electron micrographs) they poorly abstract the concepts the real-world image represents. The user navigates among these representative organelles and uses virtual instruments to conduct experiments. All navigation with a module is learner-directed; there is no predetermined sequence of events. This important feature allows the student to construct his or her own exploratory learning pathway (Duffy & Jonassen, 1992). Future Virtual Cell versions will permit the student to travel into the cellular organelles and perform experiments related to specific organelle functions.

As a network-deliverable learning environment, the Virtual Cell allows any user to always have access to the latest version of the software. Importantly, this is an environment in which users from anywhere in the world can occupy the same cell and explore and solve problems together. Students simply need a computer with Netscape 4, a Java 1.1-capable web browser, with the

CosmoPlayer plug-in installed.

The Virtual Cell consists of three software elements: 1) a collection of VRML scenes that represent a virtual laboratory, the interior of the cell, and the interior of cellular organelles; 2) a Lambda MOO server and database that contains the textual material (help file and experimental output data) and controls the single and multi-user interactivity; and 3) a Java applet interface. The VRML worlds provide the visual context, while the Lambda MOO server and database and the Java interface controls the interactions. Lambda MOO runs in the background on a network server and manages the activities of the multiple users who simultaneously connect to and interact with the VRML scenes and their associated data.

Using the Netscape 4 web browser, students launch a Java applet, which provides a connection to the MOO server, where cellular processes are simulated and multi-user viewpoints are synchronized. The Java applet also launches an interface to the VRML representation of the Virtual Cell. To the student, the Virtual Cell appears as an enormous navigable space where diagnostic reasoning and visually based problem solving support the completion of assigned experimental goals.

The Java interface controls the interactions with the Lambda MOO server and consists of three windows. The *Virtual Cell Client Window* contains the fully interactive VRML world. Depending upon the module level the student is attempting to solve, the student will be in the laboratory, the cell or the interior of an organelle. The *Controls and Information Window* contains drop-down menus with structure and function information about the components seen in the *Virtual Cell Client Window*. It also contains a *Lab Notes* area where experimental results and dialog are reported. In addition, this window provides a text-based *User-to-User Communication* box where two students occupying the same cell can communicate. The *Experimental Action Window* contains the tools necessary to perform experiments on items in the VRML window.

In the summer of 1998, shortly after the Virtual Cell project had committed itself to the CosmoPlayer plug-in and CosmoWorlds VRML authoring program, the original developer of the Cosmo products, Silicon Graphics, Inc., sold its Windows and Macintosh versions to Platinum Technologies, which in turn were promptly purchased by Computer Associates, Inc (CAI). CAI then immediately terminated the development of the Cosmo product line, leaving the Macintosh version of CosmoPlayer in beta release and the Windows version only fully compatible with Netscape 4.08 and Internet Explorer browsers.

Soon after the death of the Cosmo product line, the Virtual Cell development group discovered that the implementation of the Virtual Cell that functioned properly under Netscape 4.08 did not running under Internet Explorer. Suddenly, Virtual Cell was usable only by schools and universities operating Windows PC's with Netscape 4.08 installed. This eliminated many of the schools that had chosen to use the Macintosh platform as well as the many schools that opted not to use Netscape since Internet Explorer is so readily available. Setbacks resulting from the use of CosmoPlayer compounded further as newer versions of Netscape 4 were released causing the installation process for CosmoPlayer to become increasingly problematic and difficult to accomplish. The Virtual Cell development group let go of its last fleeting hope that CosmoPlayer might have a workable Macintosh solution with the release of Netscape 6 when it discovered that

the Windows version of CosmoPlayer did not even install properly. After evaluating the alternatives, the Virtual Cell development group decided to steer software development efforts away from VRML specific plug-ins toward the Java2 plug-in and Java3D API.

In September of 2000, the National Science Foundation provided WWWIC with generous funding through an ITR proposal. With this added funding WWWIC hired additional programmers to further develop its IVW projects and specifically begin developing a Java3D-based VRML application for distributing its 3D IVW's through multiple browser types across multiple OS's. The first of these Java3D IVW's, the Java3D version of the Virtual Cell, is due to be released in the spring of this year.

One of the most cumbersome obstacles to developing IVW's has been cross-platform/browser/OS delivery of the IVW applications/applets. The Java2 Platform Standard Edition (J2SE) has emerged as a viable desktop application development environment (Fielden, 2000). Runtime environments are now available for all major computer OS's with the exception of Mac OS, and even that will be made available once OS X is released (http://java.sun.com/j2se/1.3/jre/; Steinberg, 2001). The Virtual Cell development group's use of the J2SE/Java3D combination addresses cross-platform and usability issues that CosmoPlayer does not.

The Netscape vs. Internet Explorer issues are effectively handled by the 1.3 JRE plug-in, the latest version of the J2SE runtime environment for web browsers. An example of an effectively implemented J2SE/Java3D applet that can easily be launched from either browser, an applet version of the DANA software, can be found at http://zydeco.cc.ndsu.nodak.edu/~flarson/ATL/. This same applet handles different OS's just as well, though the user must ensure that he/she has the appropriate OS native Java3D libraries installed on the user's computer.

The Virtual Cell development group had some initial reservations concerning the use of Java3D due to the need for OS dependent native library installations of the Java3D Runtime classes. The decision was made to move ahead with a Java3D version of the Virtual Cell in spite of this obstacle hoping in the future that the installation of the Java3D native libraries could be automated. According to Michael A. Schulman, Product Line Manager for Java3D / JAI, including the native Java3D jar files in an applet is possible, thus enabling the automated process as the group had hoped (Schulman, Personal communication, February 20, 2001). In fact, using Java Web Start, a Sun Microsystems product to be discussed later, automatic installation of native library files is theoretically quite easy.

User comments regarding 3D navigation difficulty in the Virtual Cell is another usability issue addressed by the Java3D implementation of the Virtual Cell. The use of the CosmoPlayer plug-in forced a multi-window Graphical User Interface (GUI) that was not only more difficult to implement than expected, but was more confusing for the student to use as well. The default navigation tools offered by CosmoPlayer were also confusing to students who lacked experience using them. The use of the J2SE/Java3D combination gives the Virtual Cell development group the power to integrate the multiple windows into one easy-to-use GUI. This integrated GUI is currently under development and will most likely be implemented in the spring release of the Java3D Virtual Cell.

Another offshoot of the Virtual Cell project is the development of a J2SE/Java3D level editor for the project's IVW. Future versions of the IVW level editor will provide tools so robust that educators not associated with Virtual Cell development will be able to create their own IVW level implementations without having to know either the MOO or Java programming languages. The first release of the IVW level editor will come around the same time as the initial Java3D Virtual Cell release. Knowledge learned from the implementation of this technology will be leveraged for use with all other IVW projects.

Geology Explorer

The Geology Explorer (Saini-Eidukat, Schwert, & Slator, 1998, 1999; Slator et al., 1998; Slator, Schwert, & Saini-Eidukat, 1999; Schwert, Slator, & Saini-Eidukat, 1999) is another IVW where students assume a geologist's role on an expedition of exploration to the mythical "Planet Oit." On this fictional planet, students participate in field-oriented expedition planning, sample collection, and "hands-on" scientific problem solving. Similarly to its sister project the Virtual Cell, a Lambda MOO server controls the Geology Explorer's planetary simulations.

The first time a student plays the game, they are assigned a primary goal and a secondary goal. Their primary goal, worth 100 points each, is to identify one specific mineral that is somewhere on the planet. Their secondary goal, worth 25 points each, is to identify any rock or mineral they find along the way. After being informed of their goals, they are able to roam freely throughout the world. They may head to a store to purchase instruments, a museum to observe samples of rocks and minerals they may find on the Geology Explorer, or head out into Oit's many exotic locations. One of the first beings that a student is likely to encounter is a software-based tutor.

Tutor intervention is one of the most important components of the Geology Explorer. There are 3 major types of tutors: the Exploration Tutor, the Equipment Tutor, and the Geology Tutor. The Exploration Tutor leads the student to his/her primary goal by informing the student of when he/she has walked past the student's goal. The Equipment Tutor suggests instruments and equipment that the student should purchase so he/she may perform the necessary field experiments that properly identify the student's primary goal. The Geology Tutor is similar to a professional geologist in the field. This tutor comes to the student after he/she has incorrectly guessed the name of a rock or mineral. This tutor then informs the student on several issues such as possible tests that the student has not yet performed, but may help in identification, why the student's guess was incorrect, and how the student's guess is different from the rock or mineral that he/she has observed.

Since the original implementation of the Geology Explorer, there have been a number of additions and improvements to the interface and the material presented to the students. There are plans to expand the tutor interface to provide more conversation based tutoring where students can interact with the tutor, asking it specific questions or giving it answers to questions it asks. Since the inception of the text-based world, the Geology Explorer development group has created and tested a Java-based graphical client. In building this client, the group has digitized well over 80 rocks and minerals by placing a rock sample covered with a black cloth on a flatbed scanner to produce original, non-copyrighted graphics. Artists working for the development

group have also created pseudo-3D background images for each "room" in the IVW. There are also graphical representations of the Oit planetary map, instruments, and samples that the players have taken. A help interface has been implemented and is constantly being expanded and reformulated into a more efficient tool.

There are also a number of additional modules in development, including an interpretive module and a hydrology module. The interpretive module teaches students landscape interpretation and the process of discovering what geologic forces fashioned the geological formations of a particular area. There is presently one such module on Planet Oit. This module allows students to enter a small geological area and determine the structure of its formations. Using geological principles, students must analyze the result of various experiments and observations to develop a hypothesis concerning these formations. Students who correctly interpret the data are able to deduce that the same geological forces that created the dike formation also formed the area's landscape. The hydrology module is the second of the two experimental modules and is in very early development. The intent of this module is to teach students the geological concepts that predict river discharge, a river's power potential, and other more advanced hydrologic concepts.

The Geology Explorer development group is presently analyzing the feasibility of creating a new planetary environment where more advanced geological topics can be presented to students. In building this advanced environment the group hopes to incorporate and dramatically extend the dynamic 3D visualization and construction technologies currently being investigated by Virtual Cell and DANA development groups. WWWIC, and more over the Geology Explorer development group, considers an enhanced visually stimulating IVW a much more conducive environment for students to discover and explore the simulated role of a geology researcher and therefore provides a superior mode for presenting the practices, experiments and resources of the discipline.

Digital Archive Network for Anthropology (DANA)

Where most other WWWIC projects are education centered IVW's, DANA is a project that has as much to offer in the form of research benefits to the discipline of anthropology as it does to the education of its students. The NDSU Archaeology Technologies Laboratory (ATL) conceived the DANA project idea. Intended to be an Internet-based network of interoperable databases forming a global Digital Archive Network for Anthropology, the network will link researchers, students, and the general public to realistic, accurate, visual representations of artifacts, fossils, and other archived objects. This federation of databases will differ from other anthropological archives in several ways. Most notably, it will contain 3D models of material objects that are sufficiently precise to allow for a wide range of detailed measurements through the application of specially created "virtual calipers" – 3D measurement tools – developed for use in a J2SE/Java3D environment (Clark, Bergstrom, Landrum, Larson, & Slator, 2000).

The ATL, in cooperation with Information Technology Services department at NDSU, serves as the administrative hub for DANA. Prototypes of the DANA architecture, critical software (applets, servlets, and virtual tools), database template, and the initial database have been developed. DANA is already a working piece of J2SE/Java3D-based software that is being extended to provide a geographic and materials-based interface for two preliminary test

databases. Institutions involved in the project can use generic SQL statements to create database tables and populate them from spreadsheets. The SQL commands are as generic as possible so they can easily be adapted to any SQL database. A Java JDBC servlet has been created to handle query traffic for both Oracle and PostgreSQL, and soon servlet support will be added for Informix, DB2, mySQL, SQL Server, and others. The use of spreadsheets minimizes the learning curve for data entry, thus encouraging participation in the DANA project.

The primary task of the DANA institutions will be the archiving of anthropological data in textual and visual forms. The set of textual records will be very large, including records stored at the NDSU site and at a number of other sites, and will be accessible via both Internet2 and standard Internet connections. Efforts to organize, navigate, and comprehend large data sets with complex information and high-resolution graphics will work most effectively with the next generation Internet. The broadband network of Internet2 will provide a smooth and reliable system for comparatively rapid accessing of large data files. For those people without Internet2 access, the database will contain models in at least two levels of compression in order to best accommodate the user's hardware capabilities and bandwidth.

Researchers wishing to use DANA simply open a web browser and point it to the following URL: http://atl.ndsu.edu/archive/dana.htm. Once there, scripts embedded in the code of the HTML document checks the researcher's computer to see if Java Web Start (JWS) has previously been installed. If it is not, the scripts redirect the researcher's web browser in a user-friendly manner to the JWS download and installation URL located at "http://java.sun.com/cgi-bin/ javawebstart-platform.sh?". The Java 1.3 Runtime Environment is installed at the same time that Java Web Start installation has been completed. Following the installation, the researcher returns to the original URL and installs the Java3D Runtime files for his/her computer's OS if necessary. Future implementations of DANA through JWS will automatically download and store the appropriate Java3D runtime files for the researcher's OS. This feature is already available in JWS through the jnlp "resources" XML tag (http://java.sun.com/products/javawebstart/jnlp-1_0-spec.pdf). If the Java3D Runtime is already installed, then all that is required is to click the "Launch DANA Application" button. The second time the researcher launches the DANA application in this manner, JWS will provide the researcher the opportunity to place a shortcut on the his/her desktop so in the future the researcher will not ever again need to launch a browser to use the DANA application.

Once the DANA application is launched, the researcher enters the global archive through a login box that allows access to the search interface. Initial browsing uses a global, geographical search through six levels of increasing spatial specificity: global regions (e.g., Oceania), global subregions, individual country, and primary, secondary, and tertiary levels appropriate to the country (e.g., in the US, state, county, & township). When the desired geographic level is reached, the user can continue the search by material category (e.g., stone, ceramic, etc.) and artifact type (e.g., adze). The search is then refined by querying the database for some set of attributes (e.g., from Oceania, Polynesia, American Samoa, Tutuila Is., Vaifanua County, Aoa Valley, all basalt adzes with the following attributes: shoulder index, 45-80; length, 50-100mm; fully ground; quadrangular cross-section; from dated contexts of 2000-3000 BP). The server software will search the DANA databases and join the result sets into one listing of object IDs for database entries that meet the search specifications. From the query-result list, the user can select the specific artifact(s) for which he/she wishes detailed information by accessing specific

database tables: attributes (metric and non-metric); provenience; chronology; documentation (e.g., location of artifact, when it was scanned, relevant reports or publications, etc.); and images.

Accessible images will include 3D models, 2D digitized graphics of photos, drawings, site maps, and stratigraphy profiles, etc., depending on availability. Currently, DANA allows for only one set of Polynesian artifacts, that of Samoan adzes, to searched. Of the Samoan adze collection there are four viewable, decimated 3D models. However, in the near future a 3D model collection of hominid endocasts as well as a collection of Assyrian cuneiform tablets and Fijian adzes will be added to the DANA network.

The DANA development group joined WWWIC once the project was successfully funded through a grant provided by the Northwest Academic Computer Consortium (NWACC; http://www.nwacc.org/). As an attempt to generate projects that conform to the nine principles of WWWIC research, the DANA development group has begun work on an IVW that draws from the strengths of the DANA network. The DANA-related IVW known as the Like-a-Fishhook Village (LFHV) project is being developed as a cultural teaching resource to inform the general public and North Dakota State Museum patrons about the significant impact that the coming of white Americans had upon Native American cultures.

The LFHV is based on the historically and archaeologically documented Like-A-Fishhook Village, also known as Fort Berthold Indian Village. As the last earth-lodge settlement of the Northern Plains, the site documents an extraordinary episode of cultural transformation. The village was founded in the aftermath of the devastating smallpox epidemic of 1837 that drastically reduced the population of plains tribes. The Hidatsa, Mandan, and Arikara peoples founded the village as a result of this destructive epidemic. At about the same time as the Hidatsa built their first earth lodges, a white trading company established a post at the site, with log structures and a stockade. This trading post eventually became know as Fort Berthold (dubbed Fort Berthold I by G. Hubert Smith). In 1851, a new trading post (Fort Berthold II) had been formed by a different trading company, which replaced the first (Smith, 1972).

The ATL will conduct a 3D digitization project to create 3D models of LFHV archaeological artifacts to be stored on the DANA network, and from which the IVW will dynamically draw much of its 3D content. The LFHV project will draw on technical experience garnered from the development of Virtual Cell, Geology Explorer, and DANA.

Conclusion

For the past several years, WWWIC has continuously developed tools to allow students to explore virtual environments via web-based Immersive Virtual Worlds or IVW's. These worlds provide opportunities for students to assume the roles of scientific researchers in several disciplines such as Cell Biology and Geology. These IVW's take the form of multi-user environments/games so that students may share the role-playing experience with other participants in order to gain a more complete understanding of the material being presented.

Interface usability is an important aspect of IVW development. Scenario tests suggest that students who use IVW's are as satisfied with their IVW learning experiences as they are with

traditional study methods. However, WWWIC is constantly seeking to improve the IVW user experience. This has lead the WWWIC IVW projects to investigate innovative methods for implementing Java technologies such as J2SE and Java3D. Though the content for each IVW project is relevant to the academic discipline for which it seeks to inform, many of the technological developments pursued by the development group can be leveraged to solve problems encountered by all WWWIC projects. The problems include, but are not limited to cross-browser/platform compatibility and interface usability.

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