Dingwall, L., S. Exon, V. Gaffney, S. Laflin and M. van Leusen (eds.) 1999. Archaeology in the Age of the Internet. CAA97. Computer Applications and Quantitative Methods in Archaeology. Proceedings of the 25th Anniversary Conference, University of Birmingham, April 1997 (BAR International Series 750, CD-ROM). Archaeopress, Oxford.

Virtual Worlds for Archaeological Research and Education

Donald H. Sanders

Abstract

The use of virtual reality for archaeology has only recently begun to take full advantage of the technology's abilities to create near firsthand experiences of ancient buildings, sites, and environments. Virtual worlds can be much more than sets of fancy pictures; objects throughout the worlds can be linked to text, image, and sound databases permitting self-guided educational or research virtual tours of ancient sites in which users can learn about history, construction details, or daily life with a click of the mouse. Worlds programmed in VRML can be sent over the Internet or run off CDs providing an interactive and exciting research experience. Alternative publications can supplement or supplant traditional paper-based source material; for instance, a 3D computer model can be a visual index to an excavation report. The same models and virtual worlds can also be used for up-to-date instructional materials for public schools or museums directly engaging students or the general public in a participatory learning experience utilizing the very latest archaeological evidence. We can create a globally integrated and interactive system of linked virtual worlds for teaching, research, archaeological fieldwork, museum exhibitions, and on-site interpretation centers. Utilizing virtual reality as the container to which all other data and image types are linked offers unprecedented access to information. Whether computers help to change the questions we ask of the past may depend on the techniques chosen to visualize the answers.

1 Introduction

Imagine this in our schools: "Today, class, we will study the civilization of Greece, not by watching a movie or by listening to me tell you about it, but by visiting an ancient Greek farmhouse and learning what life was like over 2000 years ago. Each of you may wander freely around the house, explore the rooms, and watch the farmer at work. If you have any questions, just access your multimedia kit."

Figure 1. View from the Learning Sites virtual world of the Vari House, Greece. Image copyright 1997 Learning Sites, Inc; reprinted with permission .

What a wonderful learning experience! Moving through virtual reconstructions of distant places and past times! The technologies, including virtual reality and the information superhighway, are already accessible in many classrooms around the world. However, for virtual reality to have its best, most positive impact on education, the content of the virtual worlds should be based on actualities, like the lifestyle on an ancient Greek farmstead (see Fig. 1) or the religious practices of an Egyptian priest (see Fig. 2). Why invent a hypothetical setting in order to examine ancient daily life when an archaeologically sound reconstruction of a real one can teach so much more.

Figure 2. View from the Learning Sites virtual world of Temple B700, Gebel Barkal, Nubia. Image copyright 1996 Learning Sites, Inc; reprinted with permission.

With the same archaeologically based data we can envision another scenario: "Welcome to the archaeological Holodeck (my apologies to those readers who are not Trekkies). In the totally immersive virtual environment before you, you have the ability to walk around in any of the ancient structures, pick up and examine the artifacts, watch virtual inhabitants, study their behavior, even destroy all or part of the site under various conditions. You may even replay all or part of the destruction scenes over and over, testing alternative hypotheses, until the outcome matches the actual archaeological record."

Are both situations a bit too fantastic? Are they fine for the special effects wizards of science fiction, but not for serious education or research? This paper will clarify just how close present possibilities are to making these proposed scenarios into serious realities for educators and researchers.

The use of replications of real physical environments for instruction and diversion has been around for a long time. Throughout human development people have attempted to capture the essence of an experience and make it educational and enjoyable for others (Pimentel and Teixeira 1993:25-27). Cave painting, storytelling, sculpture, theater, music, and books all offer other views of the world, other experiences, other beliefs, and other times to stimulate the imagination, to instill wonder about the fantastic, and to speculate about the spiritual. Radio, television, and motion pictures have continued the quest for increased realism and the sense of being there.

"Visualization is a recognized means of presenting data and concepts... [increasing] comprehension and assimilation" (Auld and Pantelidis 1994:29). Thus, in education, textbooks are illustrated and audiovisual materials are widely used, especially in our discipline. Virtual reality is a new medium that needs to be productively incorporated into the learning process, whether for instruction or for research (Auld and Pantelidis 1994:29). Although military, government, and scientific applications of simulations and some form of virtual reality have been around for decades, this technology is largely unexplored for archaeological education or for archaeological data collection, analysis, and publication. Allowing students to become absorbed by another reality and totally engaged in a participatory learning experience could truly revolutionize the dissemination of archaeological material and the interdisciplinary themes that it touches, such as history, geography, architecture, anthropology, astronomy, and mathematics. The opportunities afforded by just such an application of virtual reality will be my focus here.

2 History and definition of virtual reality

Although virtual reality is generally perceived as a new field (see Fig. 3), many of its underlying concepts and technologies have been around since the 1920s when Link Corporation manufactured training devices that simulated fighter plane cockpits (for brief histories of virtual reality and related technologies, see e.g., Littman 1996:428-29; Pantelidis c.1995; Pantelidis 1993:23-24; Pimentel and Teixeira 1993:41-71). During the late 1950s, cinematographer Morton Heilig created a simulator known as Sensorama, which could generate city smells, wind sensation, and vibration as a participant sat on a motorcycle and went on a simulated ride through New York City (Pimentel and Teixeira 1993:38-40). This device had many of the features of a VR system except that the route was fixed and the experience was not truly interactive (two criteria of true VR).

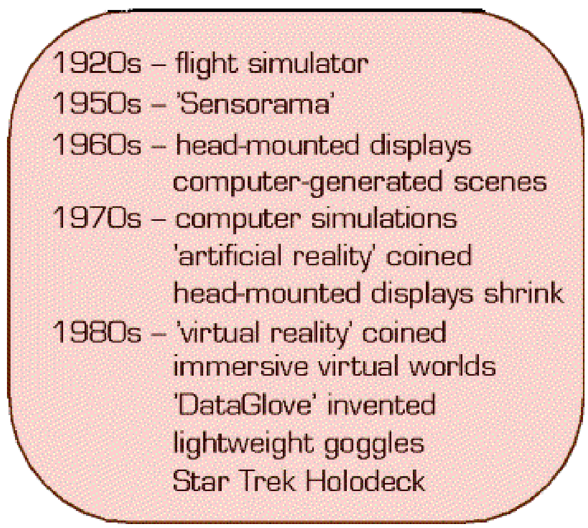

Figure 3. Brief history of virtual reality milestones.

The status of VR pioneer is often given to Ivan Sutherland, who first proposed the use of stereographic head-mounted displays in the early 1960s so that users could look around a computer-generated room simply by turning their head. In the early 1970s, General Electric’s Electronics Laboratory built for the US Navy the first flight simulator that used computers. About the same time, Myron Krueger coined the term "artificial reality" and began developing computer-controlled responsive environments (Krueger 1993); and the MIT Media Lab produced a simulated tour through Aspen Colorado, in which participants could drive down a virtual street and enter and explore virtual buildings.

The 1980s brought rapid changes to VR technology. Jaron Lanier, a founder of VPL Research, Inc., is credited with coining the expression "virtual reality" to distinguish between the immersive environments he was creating and traditional computer simulations. Thomas Zimmerman, co-founder of VPL, worked with Lanier to develop a glove for grasping computer-generated objects in virtual worlds. NASA developed goggles that allowed the wearer to look around a graphic landscape portrayed on a computer screen while hearing synthesized speech and 3D (binaural) sounds, and grabbing objects with their hands. Communication and feedback with a computer-simulated environment was direct; no contact with the computer was necessary.

In 1992, the movie Lawnmower Man introduced the concept of virtual reality to the public. By the mid-1990s it was possible to reach out and touch virtual objects and to feel different textures and sensations; and perfume companies were experimenting with virtual smells to send odors electronically from lab to lab.

Several distinct types of virtual reality have now emerged (Krueger 1993: Pantelidis 1993:23): artificial reality (complete, unencumbered, full-body, multisensory participation in computer events), augmented reality (simultaneously receiving supplemental virtual data about the real world while navigating around a physical reality), immersive reality (the eyes and ears or other body senses are isolated from the real environment and fed only information from the computer, providing a first-person interaction with the computer-generated world), telepresense (the use of robotic vehicles and viewing systems to give a feeling of being present at remote real locations, including the ability to manipulate objects at that remote location), and CAVEs (or Cave Automated Virtual Environments, introduced by the Electronic Visualization Laboratory at the University of Illinois in 1992, which are essentially rear-projection systems for three walls and a floor, projected in stereo and viewed with stereo glasses; as a CAVE viewer moves, a location sensor tracks movement within the display boundaries; the correct perspective and stereo projections of the environment move with and surround the viewer, so that total immersion takes place; the viewer thus has the impression of walking into an enclosed space, without being physically linked to a device). Each of these types provides different degrees of immersion, interactivity, and unencumbered navigation. For purposes of this paper, I define VR as an interactive, self-directed, multisensory, computer-generated experience providing the illusion of participating in a synthetic three-dimensional environment.

3 Virtual reality for education and archaeological visualization

The use of this advanced technology for education has not had a long history, and its use for archaeology has had an even shorter life. Only in the past six or seven years has there been any serious consideration of integrating VR into the classroom (see some examples in, e.g., Littman 1996:446-50). One of the first experiments took place at Newcastle-upon-Tyne, England, at the West Denton High Schools, in 1991 and 1992. Three virtual environments were designed with desktop systems: a dangerous factory, to explore health and safety issues; an intelligent city, in which participants learn a foreign language while trying to navigate normal urban activities, like going to the theater or taking a bus; and an outdoor sculpture park, to examine issues relating to alternative uses of public lands (Clark c.1992).

The Human Interface Technology Lab (HITLab) at the University of Washington, Seattle, began exploring educational uses of VR in 1990; their VRRV project, the virtual reality roving vehicle, brought VR technology to 70 schools during 1994 and 1995. The goals were to demystify the hype of virtual reality, expose pupils and teachers to the capabilities of high-end machines, and see whether school-age children would respond to learning through the new medium (Winn 1995). More recently, the Virtual Reality and Education Laboratory at East Carolina University, Greenville, North Carolina, has been training teachers to integrate VR into their schools' curricula (http://eastnet.educ.ecu.edu/vr/vrel.htm).

Consequently, VR is being used in public schools for such diverse subjects as history, alphabet recognition for learning disabled children, atomic modeling, electromagnetic spectrum studies, and literature. Archaeology has been absent, except tangentially in the teaching of history. Currently, Learning Sites' archaeologically based educational virtual worlds are being field tested in American and Canadian schools (Sanders and Gay 1997a).

This is not to imply that virtual reality and archaeology have yet to be formally introduced. As the sessions and papers of this conference attest, virtual reality has found a ready audience among archaeologists, although the use of such simulated environments for archaeological visualization has been tested only for the last three or four years, and basically for two main purposes. The first purpose has been for single specialized research projects (such as the recreation of the Egyptian Fortress of Buhen, now submerged under Lake Nassar, done by Bill Riseman; the virtual modeling of Egyptian tombs at Saqqara and the Fayum, by the University of Pisa; the modeling of the Lion Temple at Musawwarat es Sufra, Sudan, by students at Humboldt University, Berlin; the virtual recreation of the caves at Lascaux, by architects and archaeologists at the University of Cincinnati; the Giza Plateau models, by the University of Chicago; and the virtual walkthroughs of an Assyrian palace generated at the University of Pennsylvania, Philadelphia).

The second main purpose has been to demonstrate the prowess of in-house programming or the power of high-end systems (such as the reconstruction of the Tomb of Nefertari by ENEL, the Italian power and light company; and the recreation of the theater complex of Pompeii by the SIMLAB at Carnegie Mellon University, Pittsburgh; both of which require high-end machines to run). The issue of producing virtual worlds to run on machines costing $80,000 to $200,000 versus developing them for PCs is a topic to which I will return shortly, though I will mention now that it is possible to generate equally high-resolution graphics, frame rates, and degree of interactivity on Windows95™- or WindowsNT™-based desktop machines using off-the-shelf or free software (see Fig. 4).

Figure 4. View from the Learning Sites virtual world of Temple B700, Gebel Barkal, Nubia, showing the high-resolution obtainable on desktop PCs. Image copyright 1996 Learning Sites, Inc; reprinted with permission.

Despite growing interest in archaeological virtual worlds, rarely has VR been integrated into the educational process either to teach archaeology or as a medium for presenting archaeological methods and theories for teaching related social studies or humanities subjects. Neither has VR been used yet for generating truly innovative multimedia publications, nor for creating interactive visual databases for customized search and retrieval. Learning Sites includes among its primary goals the nudging of the profession in those directions. For the remainder of this article, I will focus on three main points related to virtual reality for archaeological research and education:

1. What impact can virtual reality have on the various aspects of archaeological research, including excavation, data analysis, and publication?
2. How can archaeology-based virtual reality content influence instruction? Can VR assist and supplement the teaching process at all levels, can it move from adjunct audiovisual aid to complete curriculum framework? Can distance education become not merely feasible, but an enjoyable part of everyday learning?
3. How close are we to realizing those two scenarios described at the beginning of this paper?

4 Traditional archaeological visualization and publication methods

A bit of background on how our profession has traditionally chosen to visualize the past will assist in placing current techniques into historical context. Since the 18th-century beginnings of our discipline, the preferred methods for illustrating built environments and artifacts for research and publication have been plans, sections, and elevations. Not coincidentally, these are the very same illustration methods needed and used by architects for constructing new buildings--buildings designed in revival styles that depended for accurate details upon those very same archaeological drawings. This symbiosis between archaeology and architecture continued until the mid-20th century. Although, occasionally, perspective or isometric renderings were made for archaeologists, from the very start, archaeologists not only depended on architects to visualize ancient monuments, but also relied on the drawing techniques and imagery conventions of the architectural profession. This was true for research, instruction, and publication (Sanders 1991, 1988).

Increasing use of three-dimensional visualization techniques and computer simulations began in the 1980s, as personal computers made an appearance and the power of high-end machines was made available to archaeologists through their universities. For example, 3D models of the Roman complex at Bath were used for educating the public and for testing previous drawn reconstructions; 3D models of the excavations helped the archaeologists at the Early Bronze Age site of Klinglberg St. Veit in Austria; and 3D models of the stratigraphy at a prehistoric site in the state of Wyoming were used by excavators for their research (Reilly 1992:149-66).

Despite the increasing use of computers since the early 1980s, one bottleneck has remained, and that is the time lag between recovery of the excavated evidence and publication of that evidence; between uncovering and placing between the covers. Things are certainly changing. There is a noticeable shift of late in the sharing of information among us, via email, listservs, and special Web pages established to publicize specific sites. Yet how much information is actually being released, of all that is recovered? How much is still held back pending full publication? Whether or not recently excavated evidence should be immediately released without first having been thoroughly analyzed and officially published is a question to wrestle with, as other research and publication technologies advance.

5 Virtual reality for archaeological data collection, analysis, and dissemination

5.1 Virtual reality for archaeological research

The integration of computer technologies into the process of analyzing archaeological data is not an earth-shatteringly new concept. However, the application of computer technologies to the collection, study, publication, and preservation of archaeological material is a newer approach, and one that could produce a radically new research tool. By digitally recording as much information as possible along the way, from excavation through analysis to publication, it becomes relatively easy and quick to produce an interactive, three-dimensional virtual recreation of a site, which researchers can visit and ask questions about as if they were at the site and as if they had access to the full range of material recovered.

Imagine being able to walk through a virtual site, enter an excavated building (or the building as the excavators have envisioned its reconstruction), study the activity areas, view the stratigraphy, walk up to an artifact, select it, retrieve contextual, chemical, and formal information about it, and read associated references about similar artifacts on the site or at other sites. Imagine studying the object closely from all sides, as if you actually had it in your hand. Such use of virtual reality goes far beyond both education and diversion, providing a serious research tool for archaeologists.

Virtual reality, Java, and the Internet make this total approach possible right now. We can re-create ancient built environments as they were excavated or as scholars reconstruct them. Within these environments we can re-place the artifacts as they were found and link to those objects texts, photographs, and narrations to provide the researcher with as much information as possible about an object. We at Learning Sites have been working on just such a research tool, one that will be deliverable either on desktop PCs or over the Internet (see Fig. 5).

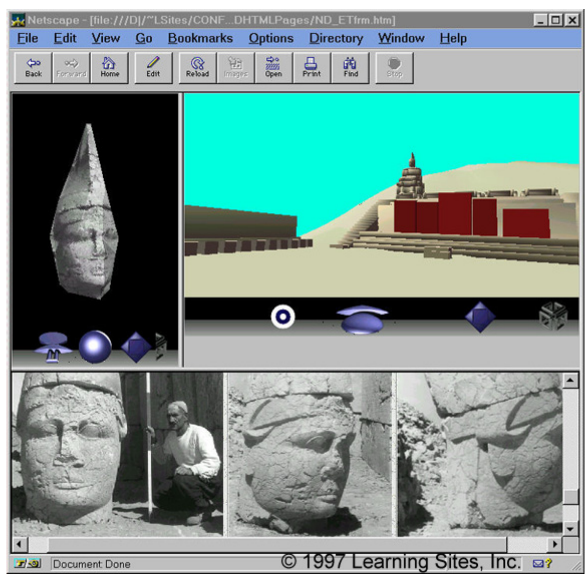

Figure 5. Multiple views from the Learning Sites virtual world of Nemrud Dagi, Turkey, showing links between: the virtual re-creation of the East Terrace; a virtual re-creation of the head of King Antiochus I, and 2D photographs. Image copyright 1997 Learning Sites, Inc; reprinted with permission.

Virtual environments are, of course, constructions, and they are only as good at representing the original site or building as the data and interpretation that are put into them. The experience of any archaeological reconstruction cannot replace the experience of original remains, and a scholar deeply involved with the particular materials will always want to see the actual evidence and draw his or her own conclusions. But for all other levels of research such a tool presents exciting possibilities.

As a publication tool, the virtual world itself becomes the visual index to the entire dataset. Should a researcher want information about a subject, object, or space in the virtual world, he or she moves up to that item and clicks on it to retrieve links to the photographic archive, the catalogue records and database, or text descriptions about that item and associated items at the site. View maps, plans, early travellers' drawings, previous excavators' notebooks, or museum records, accessed with a click of the mouse. Research need not proceed in the mostly linear fashion of standard reports, publication need not be limited by the cost of printing color plates, and inquiries need not be restricted to word-based searches alone, since links can be made to and from 3D objects or pictures or virtual locations (Sanders and Gay 1996).

Now add to that research tool the ability to change the virtual environment as one is moving through it; software tools currently exist that allow users to, for example, choose to watch the as-excavated model morph into a reconstruction, watch how activity areas form, or test hypotheses by comparing several virtual models at once. Add to that the capability of listening as the excavator or another expert explains why the reconstruction is just that way, and why certain activity areas led to certain conclusions about the function of spaces and thus the building's use or date. This we can do today. The ability to tell the reconstruction to burn down as if by an internal fire, or burn as if it was set ablaze by an enemy attack, or watch as mudbrick slowly decays over a set period of time - this we may be able to do soon.

Thus, three-dimensional interactive digital databases, if accessed using virtual reality, become dynamic media that can reunite elements from disparate locations into a single model, re-creating an ancient world in its original complexity creating a near firsthand experience. Data about a site that has become globally distributed can be brought back into a single virtual recreation that can allow scholars to see the objects and their architectural context back together again for the first time since antiquity (see Fig. 6). This is an unprecedented opportunity for researchers.

Figure 6. View of the Learning Sites 3D model of the Great Northern Courtyard, Northwest Palace of Ashur-nasir-pal II, Nimrud, showing simulations of now globally dispersed reliefs re-placed into their original locations. Archaeological and architectural data supplied by Samuel M. Paley, Ph.D., State University of New York at Buffalo, Richard P. Sobolewski, R.A., Warsaw, Poland, and Alison B. Snyder, R.A., University of Oregon, Eugene. Image copyright 1998 by Learning Sites, inc., reprinted with permission.

Figure 7a. View of the tombs west of the Great Pyramid, Giza, Egypt. A copy photo made from new print of an 8X10" glass negative (A-634) showing tombs G2172 and G2175 (the original negative was taken on Feb. 16, 1912). Photo reprinted courtesy of the Museum of Fine Arts, Boston, Department of Egyptian, Nubian, and Near Eastern Art.

Figure 7b. Same view of the tombs west of the Great Pyramid, Giza, Egypt. A copy photo made from a recent print of the now stained 8X10" glass negative (A-634). It is too clear that significant degradation of the original image has taken place. Irreplaceable visual documentation had been lost due to loss of emulsion. Photo reprinted courtesy of the Museum of Fine Arts, Boston, Department of Egyptian, Nubian, and Near Eastern Art. The Museum is seeking assistance to preserve and digitize this irreplaceable archive.

The same digital technologies can be put to the vexing problem of cultural heritage preservation (see Fig. 7a-b). There is a profound destruction and loss of cultural patrimony occurring both among materials housed in collections and those remaining exposed at archaeological sites. We are witnessing not only the deterioration of the actual antiquities themselves, but also of the only surviving original visual records of those monuments. Digital technologies can preserve the current condition of this evidence to protect against further loss of these data.

5.2 Virtual reality for teaching about archaeology

Once the information is in digital form, it becomes even easier to turn it into 3D and virtual models, and then the models and accompanying interactive databases are easily adapted for use as educational tools for schools, for museums, and for use at the sites themselves. My second theme is virtual reality for education, which can be viewed as a variation on using the technology for research. What can be designed for interactive research, can be applied to instruction at any level--elementary school, secondary school, or for the education of our peers.

To meet the challenges of benefiting education, at any level, interactive networked virtual worlds must be available on platforms affordable to schools and museums. Such worlds, once found only in the domain of workstations and high-end computers, are now available to nearly anyone through the advent of the Virtual Reality Modeling Language. VRML makes possible the inclusion of 3D models into multimedia environments on systems that are within the financial range of pubic institutions and may allow for fulfilling the promise of distance education. Right now, thanks to VRML, the full power of 3D environments can be combined with the full power of multimedia to create an unrivaled learning experience, promoting awareness of past civilizations, understanding of different cultures, and appreciation of different places, peoples, and their cultural heritage (Sanders and Gay 1996).

Previous virtual reality environments have emphasized real-time response and the immersive qualities of the experience. However, the wider application of those worlds for education or research is limited because: (1) expensive hardware and software are required; (2) text display is rudimentary; and (3) users are unable to browse related text or pictures.

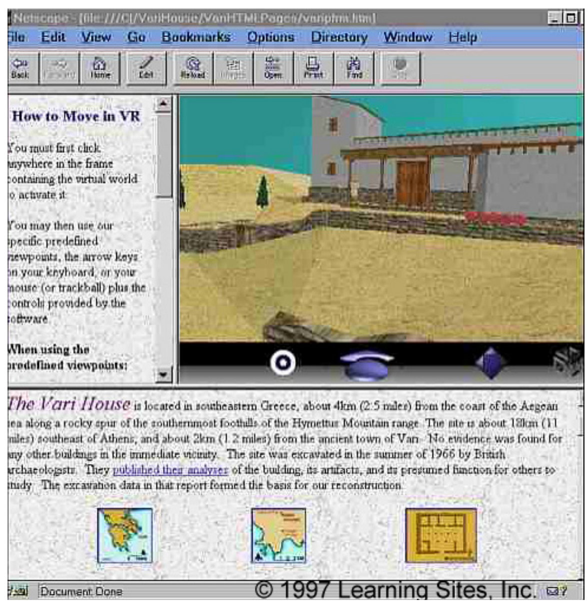

Figure 8. Multiple views from the Learning Sites Vari House virtual reality-based educational package, showing links between the VRML-based models, 2D images, and HTML-coded text. Image copyright 1997 Learning Sites, Inc; reprinted with permission .

VRML has changed that, making possible the integration of 3D data, standard HTML 2D text, pictures, and video into a World Wide Web page. Frames, multiple windows, and Java-enhanced browsing permit simultaneous viewing of 3D and 2D information. 3D environments can now be used for what they do best: allow the user to gain a full understanding of a spatial structure through self-directed exploration while retaining all the power and detail provided by the 2D text and graphic of standard Web pages (see Fig. 8).

Links between 2D and 3D data make it possible to click on a specific detail in the 3D environment and either switch to a different 3D model or bring up supporting text or pictures in a separate scrollable frame on the same window or in a different window (see Fig. 9). Hot spots in the text can affect the 3D portion of the screen and hot objects in the 3D environment can access and change the text and graphics on the Web page. Objects can move, change and react to the user. Sound can provide ambient context and additional information through narration. The result is dynamic interaction between the user and the environment.

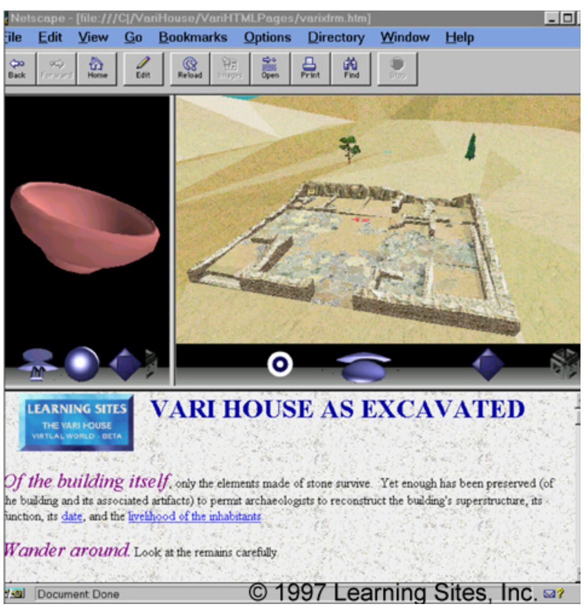

Figure 9. Multiple views from the Learning Sites Vari House virtual reality-based educational package, showing links between multiple VRML-based models, and HTML-coded text. Image copyright 1997 Learning Sites, Inc; reprinted with permission.

HTML pages can provide a curriculum framework. Anchored viewpoints and labeled locations allow the creation of self-guided or teacher-driven explorations of archaeological sites, each emphasizing different aspects of the data, from daily life of the ancient inhabitants to archaeological methodologies. This means that for education there is a fully interactive instructional tool available for teachers, one that provides for students an engaging and participatory learning environment. It gets better.

6 Conclusion

In conclusion and to address my third theme, the near future, let me say that all of the pieces needed to make the first of my two opening scenarios a reality are now in place - VRML-based recreations of ancient sites and interactive multimedia environments. The real world can be messy and harmful, and distances between important people and places are often too great. By reflecting the real world, VR allows participants to try different options without the dangers, expense, or time consumption of the real thing. VR programs are engaging, it is almost impossible to remain passive; thus the student (and teacher or researcher) are entertained as well as educated. In virtual environments participants do not just learn by doing; doing becomes learning (Krueger 1993:152).

With VR, students and teachers can explore places and things that would not otherwise be accessible to them;VR allows the disabled to participate in experiments or learning environments otherwise beyond their capacities; VR allows learners to proceed through experiences at their own pace; VR allows learners to participate over a long time span not constrained by regular classroom routines; VR encourages active participation and interaction either alone or in groups.

In classrooms of the near future, interactive, networked, multi-user, virtual reality-based education will enhance students' learning by (1) offering vicarious firsthand experiences otherwise beyond their reach or their school's ability to provide; (2) providing interaction with geographically or temporally remote locations, people or objects; and (3) providing information at levels of detail tailored to individual needs.

Schools will find the computer-enhanced future classroom financially efficient as well. With access to online teaching materials, each school system need not compile complete sets of instructional materials or full libraries, in the traditional sense; and with worldwide connections, a virtual environment will eventually link students voice-to-voice and eye-to-eye with the best instructors in the world.

Just over the horizon, then, we may find multiuser virtual worlds featuring virtual actors that move and look like real people; intelligent, thesaurus-based search filters able to match query language with database entries, enabling the inquisitive to ask detailed questions about the material associated with the virtual environments, thus providing a completely interactive online knowledgebase accessible from within virtual worlds (Sanders and Gay 1997b). Remote conferences and personalized education will follow as bandwidth improves. In addition, based on other papers presented at this conference we can extrapolate about the capacity of ground-penetrating radar and its ability to see objects still buried. Other remote sensing tools coupled with 3D graphics could stimulate a digital virtual archaeology without intrusion into or disturbance to local cultural heritage materials. Further, at last year's SIGGRAPH, a working demonstration of projection holography was shown. Now my second opening scenario begins to seem less like a fantasy.

As we move toward a digital archaeology of the near future, we can envision a process whereby excavation evidence (from the artifacts and architecture, to trench details) is digitized and sent back to a remote model shop where interactive 3D models are created and sent back to the field within a week to assist in redirecting field strategies. At the same time, the material could be fed to the Internet for comments by colleagues. The models would then be refined based on continuing excavations and peer review. The same models and virtual worlds created from them can also be used to provide always up-to-date instructional materials for public schools, museum exhibitions, or on-site interpretation centers. The entire loop thus utilizes the very latest information. We can create a globally integrated and interactive system of linked virtual worlds that can be used for teaching, research, archaeological fieldwork, museum exhibitions, and even tourism. We can also create a virtual educational community and be able to experience new knowledge domains equally with peers, instructors, and experts from around the globe.

How much and how rapidly we change our perspectives of the whole research and educational processes depends not only on the questions we ask, but equally on the content and visualizations, virtual or otherwise, chosen to illuminate the answers.

Bibliography

Auld, L W S, and Pantelidis, V S, 1994 Exploring Virtual Reality for Classroom Use: the Virtual Reality and Education Lab at East Carolina University, *Tech Trends*, 39.1, 29-31

Clark, M, c.1992 *Virtual Reality: a real context for learning? Virtual Reality and Education Laboratory*, East Carolina University, fact sheet

Henderson, J F, 1996 Virtual Reality on the World Wide Web: a survey of Web sites, *International Journal of Virtual Reality*, 2.1, 5-16

Krueger, M, 1993 An Easy Entry Artificial Reality, in *Virtual Reality: applications and explorations* (ed A Wexelblat), 147-161, Academic Press Professional, Boston

Littman, M K, 1996 Alternative Meanings through the World of Virtual Reality, in *Mosaics of Meaning: enhancing the intellectual life of young adults through story* (ed K E Vandergrift), 425-55, Scarecrow Press: Lanham, MD and London

Pantelidis, V S, 1993 Virtual Reality in the Classroom, *Educational Technology*, 33, 23-27

Pantelidis, V S, c.1995 *Virtual reality: 10 questions and answers*, unpublished document produced by the Virtual Reality and Education Laboratory, East Carolina University, Greenville, North Carolina, USA

Pantelidis, V S, *Virtual Reality and Education Laboratory bibliography on Virtual Realty and Education*, ftp://ftp.hitl.washington.edu/pub/scivw/citations/VR-ED.html

Pimentel, K and Teixeira, K 1993 *Virtual Reality: through the new looking glass*, McGraw-Hill: NY

Reilly, P, 1992 Three-Dimensional Modeling and Primary Archaeological Data, in *Archaeology and the Information Age: a global perspective* (eds P Reilly and S Rahtz), 147-173, Routledge: London and New York

Sanders, D H, 1991 Perceptions of the Pointed Arch: representations of Gothic architecture from Villard to Video Disk, unpublished paper presented at "*A Symposium in Honor of Stephen Gardner*," May, NYC

Sanders, D H, 1988 Architecture: The Neglected Artifact, in *Problems in Prehistory* (eds E B French and K A Wardle), 489-498, Bristol Classical Press: Bristol, England

Sanders, D H and Gay, E, 1996 VRML-Based Public Education: an example and a vision, *VRML Site Magazine*, http://www.vrmlsite.com/dec96/spot2.html

Sanders, D H, and Gay, E, 1997a Exploring the Past, *HyperNexus*, 7.3, 29-31

Sanders, D H, and Gay, E, 1997b Virtual Reality and the Internet in the Service of Education: the premise and the promise, *EduPort Newsletter*, 2.1, http://ianrwww.unl.edu/eduport/EDU97FEB.HTM
Winn, W, 1995 The Virtual Reality Roving Vehicle Project, *T.H.E. Journal*, 23.5, 70-74

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