ON THE DESIGN OF CLASSROOMS FOR THE 21ST CENTURY

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ABSTRACT

Classrooms which address the needs of 21st Century learning are being developed for military, commercial, and public education applications. These classrooms are designed to support multiple modes of learning, to include: independent study, collaborative learning, mentoring, visualization, and immersive learning. In this paper, we describe how classrooms can support these multiple learning modes. The paper focuses on the design of the classroom infrastructure and its support for collaborative learning. This paper draws on two examples:

- WarLab XXI, an advanced classroom developed for the Battle Command Battle Laboratory under the direction of the Army Simulation Training and Instrumentation Command, and
- *ALIVE*, an advanced classroom developed by and for the Research Triangle Institute that focuses on the application of Virtual Reality (VR) and related technologies to enhance learning.

Both classrooms provide multiple learning environments, including an immersive classroom environment that supports group VR experiences, realistic work areas for simulations and "learning by doing," and support for remote access to allow distant learning. Both classrooms provide multiple networks that support sharing and presentation of multiple media between the instructor and the class. Both classrooms provide infrastructure to allow the instructor at a central location to control the media and to present student's work to other class members in a variety of forms. The WarLab XXI application supports a form of collaborative learning where specialists from different disciplines learn to cooperate in pursuing a common goal. In this context, specialists use a common virtual environment as a shared "3D blackboard" to integrate technical information for visualization by the students in the class.

AUTHORS BIOGRAPHIES

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1.0 INTRODUCTION

1.1 Modes of Learning to be Supported by an Advanced Classroom

As shown in Figure 1, the advanced classrooms described in this paper support three modes of learning: individual study, collaborative learning, and immersive group study.

To help students learn while they live, these classrooms provide self-paced individual instruction modules for study at the office, lab, or factory using networked Personal Computers (PCs), laptops, or home PCs. These PCs either access courseware and database resources over the Internet or by using CD-ROMs.

These classrooms provide a combination of intelligent tutoring, on-demand access to know-how, and guidance on the job via networked or wireless PC.

To help students learn tasks that require close interactions with others, these classrooms support collaborative, distributed learning where multiple students at remote locations interact over the network.

To help students learn complex tasks requiring intensive group interaction and visualization of common goals, these classrooms provide an immersive group learning environment with projected Virtual Reality, head-mounted displays, and natural language interfaces for spoken commands and dialogues.

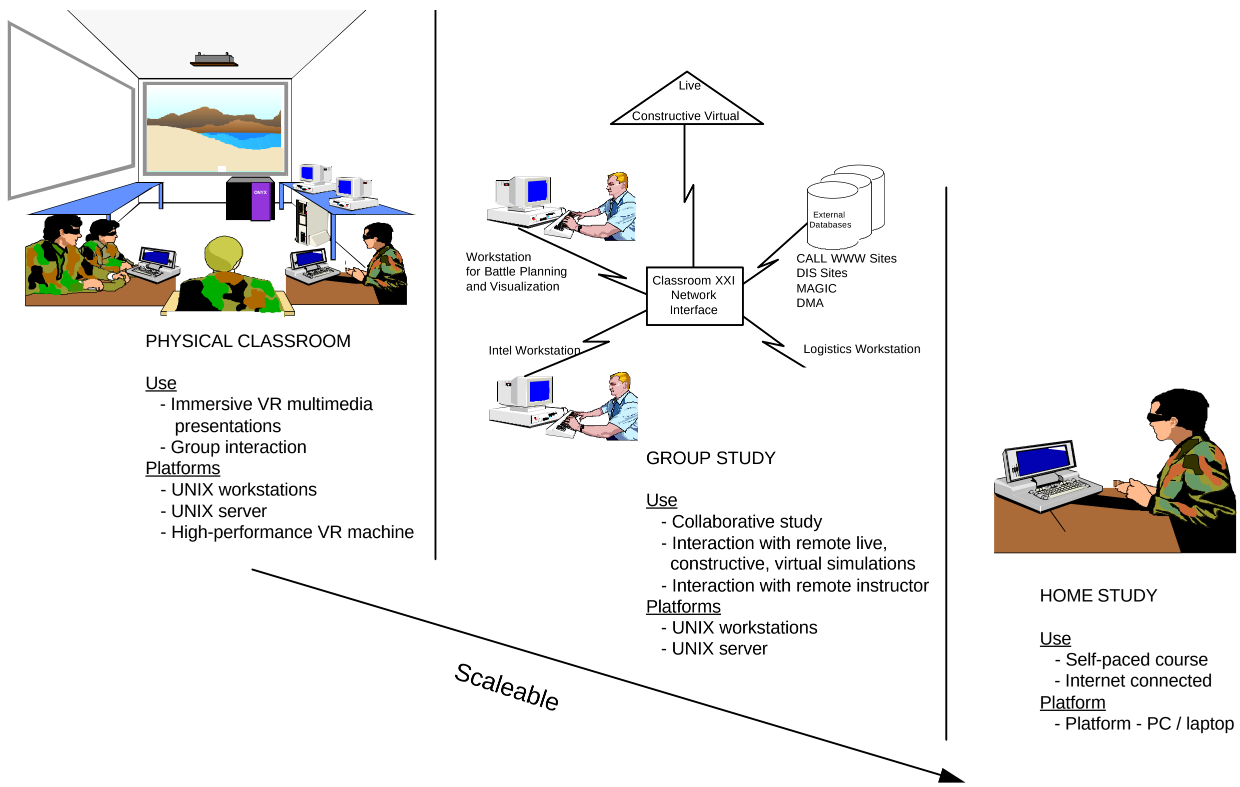

Figure 1. The Educational Methods of an Advanced Classroom Support Individual Study, Collaborative Learning, and Immersive Group Study

1.2 Elements of the Design of an Advanced Classroom

An advanced classroom consists of:

- Facilities, particularly a physical environment conducive to the purpose of the learning.
- Infrastructure, including networks and computing infrastructure that support collaboration, perception using multiple senses, and multimedia communication
- Educational materials, including software, courseware, and databases
- User support packages, including training for instructors, operators, and maintainers

2.0 TWO EXAMPLES OF ADVANCED CLASSROOMS

2.1 WarLab XXI

WarLab XXI [1,2] is an advanced classroom developed for the Battle Command Battle Laboratory under the direction of the Army Simulation Training and Instrumentation Command.

2.1.1 WarLab Physical Facilities

The physical facility consists of six distinct areas: the Immersive ClassRoom (ICR), the command vehicle mockups, the simulation area, the Video Control Center (VCC), the Network Control Center (NCC), and the server area (Figure 2).

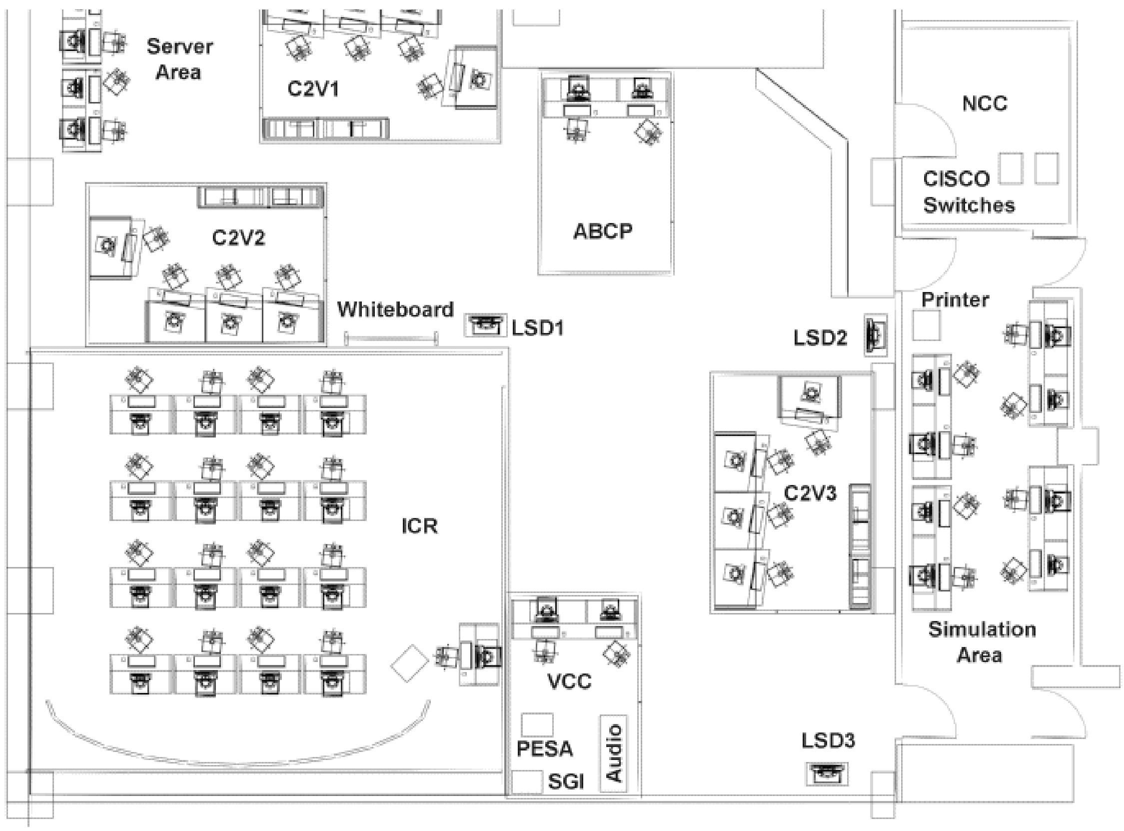

Figure 2. Floorplan for the WarLab physical facility, showing the six functional areas, command vehicle mockups(C2V1, C2V2, C2V3, ABCP), and large screen monitors (LSD1, LSD2, LSD3)

The Immersive Classroom: At the heart of WarLab is the Immersive ClassRoom, (Figure 3). The ICR is designed to support group interactions in a multimedia environment. The ICR is equipped with a large screen display system for displaying, through the video network and the audio/visual switch, graphics from a number of sources including the mockups, the servers, the video cameras, the VCRs, the high-end graphics computer, and the laptops. The screen is illuminated by three projectors so that the screen may be divided into one, two, or three smaller screens. This allows work products from multiple sources to be displayed at the same time.

Students interact with ICR displays using laptops, laptop monitors, CD-ROM drives, and video connections. The laptops are loaded with the same software as the workstations in the mockups. The instructor uses a lectern that provides a convenient briefing environment as well as a sophisticated, user-friendly interface to the controls of the audio/visual switch. It is equipped with a touch-screen display to assist the instructor in selecting a display source.

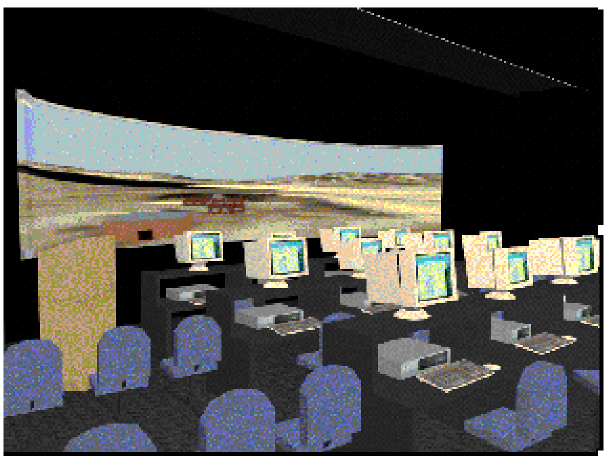

Figure 3. View of the Immersive Classroom showing the large screen display, instructor s lectern, and monitors for student laptops

The Execution Area: To support training in realistic command environments, WarLab contains four command center mockups: three Command and Control Vehicle (C2V) mockups and one Airborne Command Post (ABCP) mockup. These mockups provide realistic environments for battle planning during class exercises (Figure 4). The workstations in the mockups support the Maneuver Control System Phoenix (MCS/P) and the WarLab user interface. All the mockups are connected to the video network, which supports interaction between students in the command centers and the instructor in the ICR.

The Simulation Area: To support simulations as part of collaborative learning, WarLab includes a physically separate simulation room. This simulation room contains MCS/P workstations, a laser printer, telephone communication with the mockups and the ICR, and digital network interfaces.

Figure 4. Interior of a command vehicle mockup, showing the staff workstations and telephone headsets

The Video Control Center: To provide students and instructors with access to multimedia educational materials, there is a Video Control Center which contains an audio/video switch, video camera controls, VCRs, the transmitter for the sound system, several sound sources, and the SGI Onyx™ image generator. The VCC supports two video networks: a high-resolution network connected to the ICR, and an NTSC network. The audio/video switch allows any computer screen anywhere in the classroom to be displayed either on the large screen display in the ICR, or in any of the mockups. The VCRs allow data collected by the cameras or through the video switch to be stored for later analysis. The VCRs also provide a video server capability, so that educational video tapes from sources such as Center for Army Lessons Learned (CALL) can be used as part of the classroom experience. The Onyx™ image generator drives the 3D battlefield visualization in the ICR. It also hosts the ERDAS software which is used to create terrain databases.

There are four remotely-controlled video cameras in WarLab. The video camera in the ICR may be used to capture the instructor's actions, or may be used to collect information on how students interact during classes in the ICR and during simulated exercises. This information is collected for use by educational methodologists, and for those developing doctrine for the operation of advanced command and control systems.

The Network Control Center: The Network control center contains the equipment which supports the Local Area Network (LAN) in WarLab.

The Server Area: To support personal computer applications and to connect to the outside world via the World-Wide-Web (WWW), there is a server area, with an NT server that supports WINDD, a DirectPC server, a WWW server, and several multimedia servers. The WINDD server provides Microsoft Office functionality on the Workstations in the mockups and the simulation room, and supports a digitized whiteboard. The DirectPC server provides access to satellite communications for high-bandwidth communications, such as downloading terrain data from the Defense Mapping Agency archives. The WWW server will provide an Internet location that other Army schools can access for information about WarLab.

2.1.2 WarLab Infrastructure

The infrastructure includes a digital Local Area Network (LAN), two video networks, a wireless audio network, and a telephone network.

As the applications of WarLab have evolved, it has become clear that having multiple and redundant networks for the different media (including digital data, video, and sound) is a wise decision. In particular, the video networks are not affected by changes in the operating systems for the different computing platforms (e.g., the laptops and the workstations) which complicate the use of the digital network.

The Digital LAN: The digital LAN supports the exchange of data and files among all the workstations in the simulation area, the mockups, and the laptops in the ICR. A 10-Mbps LAN was sufficient for workstation communications. A 100 Mbps ethernet LAN provides the connectivity to the ONYX™ image generator. This provides high-speed data transfer which can be used to download large files such as terrain data for analysis and visualization. A bank of 16 modems provides remote access to WarLab databases for authenticated students.

The Video Networks: The digital LAN is augmented by a high resolution video network for video communication from the laptops, command vehicle workstations, and the image generator to the video switch in the VCC, the large screen display in the ICR, and the TV monitors outside the ICR. An NTSC video network connects the video equipment including remote-controlled cameras and VCRs to the ICR and the workstations. Using video processing software on the workstations, students can see video outputs from the video switch.

The Audio Communication Network: The audio communication network provides for the distribution of sound for the video network. The sound is run in parallel with the video. The audio network is enhanced by a PA system driven by a wireless mike that can be used by a roving instructor.

The WarLab Telephone Network: To support voice communications between the mockups, the simulation room, and the ICR, WarLab also has an extensive telephone system. This system uses the hands-free headset with earphones and mikes to allow users in the mockups to operate their workstations while talking on the phone.

2.1.3 WarLab Educational Materials

WarLab educational materials include its software and the databases that support a set of class exercises based on an existing scenario currently in use by the Command and General Staff College (CGSC).

Software: The software consists of a series of application extensions to the Maneuver Control System Phoenix (MCS/P) and the Mission Planning, Rehearsal, and Training System (MPRTS). MCS/P and MPRTS provide a common picture of the battlefield overlaid on digital maps, a capability to synchronize battle plans based upon near-real-time information and assessments from staff and subordinate commanders, and battlefield visualization.

The WarLab user interface integrates Army doctrine (as defined by the Deliberate Decision Making Process (DDMP)) with the primary command and control system used at echelons above brigade (MCS/P). The interface organizes the MCS/P data by the role of the student (e.g., Intel, Maneuver, Fire Support, Air Defense, Logistics), and by step of the planning process. The user interface supports both private and public files for each user and each step of the DDMP. The student identifies his or her role at logon time. The interface supports interaction with MCS/P tools, including communications, maps, overlay editing, and database access. The user interface provides help files and check lists for the steps of the DDMP. WarLab help files assist the user in understanding the tasks for a particular step in the planning process (Figure 5).

MPRTS is integrated with MCS/P so that MCS/P overlays can be shipped to MPRTS by the push of a button. This interface supports the transmission of unit location and unit icon information. It also supports the transfer of control measure information, such as unit boundaries and phase lines. It also supports transferring information marking restricted and highly restricted terrain.

<u>Databases</u>: A 170 km by 222 km terrain database for a playbox located in eastern Germany was developed to support the CGSC scenario. This database includes a high-resolution section textured with colorized 10m resolution satellite image data. The elevation (topography) data used throughout is derived from 100-meter level 1 DTED data. A skeleton MCS/P database for the scenario was developed which contained the information that would be provided by higher-level headquarters in a digitized planning environment.

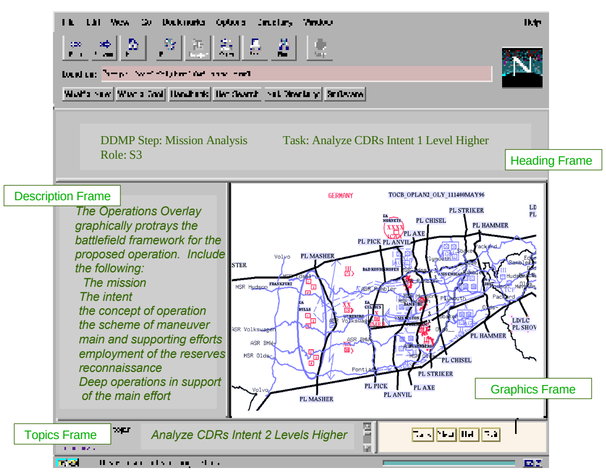

Figure 5. WarLab help file screen

For demonstration purposes, several overlays were created to show how WarLab could be used by students for collaborative learning. These overlays included: a mobility/counter mobility operational overlay (MCOO), an enemy SITTEMP showing the suspected location of enemy units, and two course of action sketches with corresponding task organizations, overlays, and narratives.

2.1.4 WarLab Support for Independent Study

The WarLab concept for independent study was based on the use of portable laptops as the student's primary tool for access to the WarLab computing and visualization resources. The laptops were configured with the same software and data as the workstations in the command vehicle mockups. The instructor could make assignments for students to prepare plans for their particular speciality by downloading data containing the current status of a student group's plan from the workstation servers and take it home for the night. In the morning, the student group leader could merge the plan data generated overnight by his specialists.

A major obstacle to effective use of the command and control software was the steep learning curve required for students to become familiar enough with the software to be productive. The WarLab team addressed this issue by designing an interface to the command and control system based on the doctrine being taught, particularly the staff roles that were assigned to the students by the instructor and the steps in the DDMP. Organizing the data in the MCS/P database by the user's role and by the step in the DDMP is a powerful aid both to using MCS/P and learning the DDMP. The interface is designed so that it is easy to change as the doctrine associated with the DDMP changes.

2.1.5 WarLab Support for Collaborative Learning

The initial application for WarLab is a tactics course. The four command center mockups support training in realistic command environments. During student exercises, students do real-time battle planning and interact with simulations in these mockups. The simulations may be executing on workstations in the simulation area, or they may be occurring at remote locations.

The command vehicle mockups are physically separated from both the ICR and the simulation room, so that observers in the ICR can watch the entire battle unfold in the virtual environment, as opposed to the Intel data available to the students participating in the battle. Similarly, the people in the simulation room need the global picture in order to provide the best simulation and the most instructive experience for the students.

2.1.6 WarLab Support for Mentoring

The visualization tool is a powerful mechanism for showing a student what is right or wrong. A Subject Matter Expert (SME) can control the viewpoint to the visualization in order to make the point crystal clear. The ability to bring together multiple sources of information and relate them visually is valuable. For example, main supply routes and routes being used by reserve forces can be shown in separate screens or overlapped to indicate a traffic jam. Terrain visualization can indicate if the terrain will restrict options.

The lectern provides a simple user interface for the instructor, so that the instructor has control over the different media and has access to the work products of all of the students, including those in the ICR and those at workstations in the mockups. The instructor's ability to use a touch screen to select information from multiple sources provides tremendous control. This helps the instructor to select and display work by particular students so that it can be shared with the group.

2.1.7 WarLab Support for Immersive Learning

WarLab's immersive classroom with its multiple panels on a large screen display is a powerful tool for group learning. Just changes in size from the screen of a laptop or workstation to a large display can help people absorb information more quickly. In particular, maps need to be seen with both a large field of view (e.g., 150 km^2) and at high enough resolution (e.g., 1:25,000) for planning. The ability to show 3D terrain is very important in helping commanders and their staff understand how terrain shapes a battle. The ability to show different products from different sources on different portions of the screen helps foster interaction in an integrated product team environment.

A controversial issue related to group interaction in an immersive environment is the lighting in the ICR. The walls of the ICR are painted black, which provides the best background for brilliant displays on the large screen, particularly when the ambient light is turned off. However, a darkened room is conducive to sleep, which is particularly tempting for students with the rigorous schedules typical at the Command and General Staff College at Ft. Leavenworth. It is also hard to see the reactions of other students, or to write notes in a darkened room. So the classroom architect must balance the desire for immersive VR with the practical issues of sleep, writing, and personal interactions. Individual study lamps on the desks solved the writing problem in WarLab.

2.1.8 WarLab Support for Visualization

The use of MPRTS has migrated from a terrain visualization tool, where a premium is placed on the realism of display, to a planning visualization tool, where a premium is placed on overlaying the plan with layers representing plans from multiple specialists. For example, earlier versions of MPRTS represented friendly and enemy forces in terms of individual vehicles. However, for planning at the division level, representing units in terms of their individual vehicles is inappropriate, and positioning individual vehicles can distract students from their larger tasks. So units were represented by icons. There are some battle operating systems that represent assets that are not usually available to commanders at echelons below division, such as EW and integrated Air Defense systems. The ability to represent the capabilities of these systems helps commanders make use of the full potential of the forces available to them. Understanding the capabilities of these systems and having mechanisms to synchronize their actions is critical to success in the digital battlefield.

2.2 Advanced Learning Interactive Virtual Environment (ALIVE)

The Research Triangle Institute has developed an Advanced Learning Interactive Virtual Environment (*ALIVE*) [3] to demonstrate, study, and assess experimental Virtual-Reality-based training methodologies and technologies[4]. RTI's experience with these methodologies and technologies has shown that when properly matched with the skills to be learned, they can reduce the cost of training equipment by a factor of 8, and reduce training time by a factor of 4 over traditional methods. These facilities allow RTI to determine the most cost-effective methods and technologies to teach the skills needed to perform specific tasks[5].

2.2.1 ALIVE Physical Facilities

The *ALIVE* facility is a two-story educational laboratory. The second floor provides an immersive group learning environment, including a large screen for viewing high-resolution VR models. The immersive environment is similar in design to the WarLab ICR, but on a smaller scale. It features a high-end graphics processor, head-mounted displays, and projection displays. The immersive environment is linked to the group environment through a local area network.

A key feature of the immersive environment is the lectern (Figure 6). It has two screens connected to two PCs. The right screen is a touch-screen that controls not only the distribution of video signals from all the sources to all the screens, but audio volume and destination and the lighting of the room. The left screen is connected to a PC that is part of the LAN, so that the instructor can upload and interact directly with educational materials while at the lectern. The display of this PC can be presented on the large screen.

The first floor provides access to different individual and group learning technologies and also houses a Control Room and a Video Control Room. The group study environment on the first floor uses a distributed network of workstations which serve as processing engines for the students and as database servers. They are connected through the RTI LAN to the Internet, and are linked to the high-end graphics processor in the immersive group learning environment. This linkage means that the results of collaboration by the students can be presented by the instructor in an immersive environment. In particular, students in the group environment, or the instructor at the lectern can control the movement through the virtual environment created in the graphics processor.

Figure 6. *ALIVE* Lectern and Large Screen Display

The first-floor facility includes several ergonomically-optimized Student Training Centers (STCs), each with its own multimedia PC and links to the *ALIVE* digital and video networks. These STCs also support the natural language interface[6].

The Control Room houses much of the computing facilities, including an Onyx™ image generator and the video and audio switching equipment. The Video Control Room provides support for interactive video conferencing and is linked by microwave to the North Carolina Research and Education Network (NC-REN) and the NCIH. These facilities provide video conferencing with universities, colleges, and secondary schools throughout North Carolina.

In order to provide more cost-effective training, *ALIVE* combines VR-based training with physical hands-on trainers (Figure 7). The student can learn the cognitive skills and the procedures in the virtual environment, and learn the motor skills and experience the physical environment with the hands-on trainer.

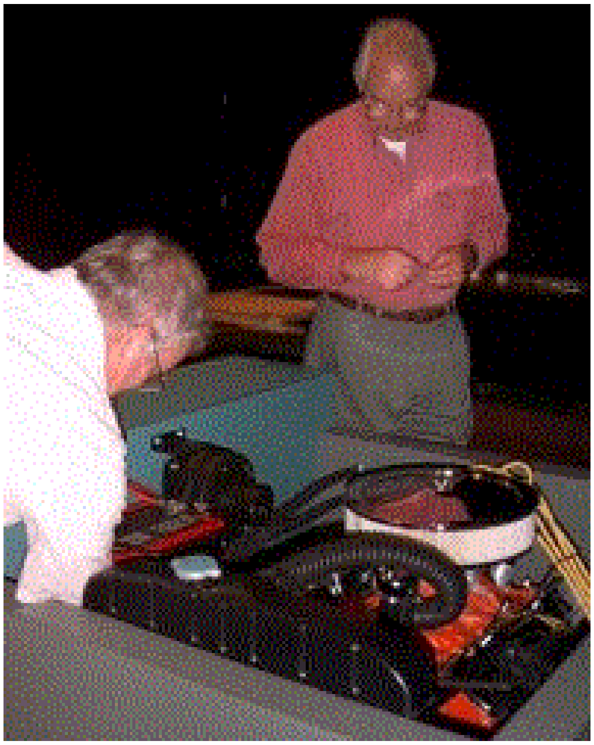

Figure 7. *ALIVE* Hands On Trainer

2.2.2 ALIVE Infrastructure

The infrastructure features a combination of digital, video, and audio networks similar to those in WarLab [2].

2.2.3 ALIVE Educational Materials

These educational materials span four broad types of applications: maintenance and inspection, marketing, planning, and medical training. All of these applications are based on learning by doing in situations where learning by doing in the real environment would be too dangerous or too expensive to be practical.

Maintenance and Inspection: The *ALIVE* educational materials include the Virtual MAintenance Trainer (VMAT), which combines actual test equipment, a virtual network of Line Replaceable Units (LRUs) in a tank, and courseware[7]. Another application is the inspection of the engine rooms of naval vessels to assess conditions which can result in equipment damage, casualties, lost operating time, or costly repairs[8].

Marketing: VR technology has been used for marketing applications, where the goal is to inform the user about a product while capitalizing on the intensity of a virtual reality experience. VR modeling has been combined with conjoint statistical analysis to allow consumers to make tradeoffs between different versions of a product[9].

Planning: The terrain modeling capabilities have been used to support not only Army mission planning applications[10], but also urban planning.

Medical Training: A training suite for emergency medical technicians is being developed[11]. Students learn by doing by applying medical techniques and using medical equipment, and are provided feedback on their efforts in terms of changes in the vital signs of a virtual patient.

2.2.4 ALIVE Support for Individual Study

ALIVE emphasizes "learning by doing." Methods have been developed to combine free play with a more structured educational process in order to maximize the educational benefits and to allow automated assessment of student progress.

ALIVE combines "learning by doing" with computerized tutoring so that the student is in control of the educational process. The student can use the computerized tutor as an assistant during free play, or the computer tutor can guide the student to a solution.

ALIVE is being used to minimize the cost of individual study environments while still providing enough realism in the virtual environment to provide the educational effects. This has led to the use of personal computers for VR-based individual study. A Pentium personal computer with enhanced graphics provides interactive 3D displays and training exercises. The use of hands-on trainers in combination with VR-based training is another approach to maximizing the cost-effectiveness of training.

2.2.5 ALIVE Support for Collaborative Learning

The *ALIVE* immersive environment allows two student displays to be shown at the same time, so that students can compare and contrast their work on assignments. *ALIVE* applications have been used in distributed environments, where a subject matter expert at a remote location guides the students through a virtual model to help in troubleshooting a difficult maintenance problem.

ALIVE technology also allows replays of student activities so that an instructor can show students good and bad examples of work on an application. Since this replay is done in a virtual environment, rather than a video replay, the teacher can modify the replay, or view the action from a different angle in order to make a point.

2.2.6 ALIVE Support for Mentoring

The *ALIVE* individual study environment provides advanced coaching technology in the form of a natural language processor interface. This interface allows the user to conduct a verbal dialog with the computer in order to maneuver through the models and make diagnoses. This interface not only provides a more friendly interface for users who are not computer-facile, but it also allows "hands-off" interaction with the computer, which can be particularly valuable during maintenance procedures or dismantling of explosive ordinances. The coaching is based on a knowledge base of the equipment being repaired and on educational approaches for teaching the student.

2.2.7 ALIVE Support for Immersive Learning

ALIVE is being used to experiment with multiple levels of immersion to determine what is most cost-effective in training. For maintenance training on M1A1 tanks, stereo views are provided using liquid crystal glasses. For terrain visualization, a large screen and high-resolution image are more important. For marketing of tires using a race-car simulation, a head-mounted display is combined with audio feedback that is consistent with the throttle position.

ALIVE addresses the issue of learning in a dark room by providing the instructor with lighting control at the lectern. Thus a skilled instructor can modulate the level of ambient light in the room to reduce sleeping in class without sacrificing the immersive quality of the VR displays. *ALIVE* also uses pools of light for individual students to help reading and writing during a presentation. Lighting options available to the instructor can also help the flow of students into and out of the room and between the STCs and the HOT.

3.0 FUTURE DIRECTIONS FOR THE DEVELOPMENT OF ADVANCED CLASSROOMS

Advanced educational methodologies and technologies will be available in 21st Century classrooms. Qualitative and quantitative comparisons must be made in order to evaluate these technologies.

Virtual reality-based training has already proven effective for teaching students how to orient themselves in a new environment and to teach new processes, such as maintenance of new vehicles. Computer-based education for higher-level tasks, such as mission planning, is still in its infancy. Use of 3D displays to assist in planning is becoming more important as de-conflicting the airspace over the battlefield becomes more complex with the arrival of new battle operating systems. For example, now a division commander may have to manage the airspace over a battlefield due to the conflicting demands of close air support, air cavalry, air defense artillery, long range artillery, and tactical missiles.

The synchronization of these assets in time and space requires new visualization techniques, and increased interaction between the command and control systems and the visualization systems.

The communications technology used in the classroom also makes it possible for these classrooms to serve as the hub for distributed learning. We are developing ways that allow students at remote locations to participate fully in educational activities. For example, the use of Distributed Interactive Simulation (DIS) technology allows students at remote sites to interact with ongoing simulations. Web-based educational materials can be prepared by instructors using commercially available word processors that provide the intellectual content and provide the context for the more interactive exercises and simulations. This gives instructors powerful tools for creating educational experiences with requiring that the instructors master the details of simulation software development.

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