The VRUPL Lab - Serving Education on Two Fronts[1]

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ABSTRACT
Undergraduate research laboratories enhance education by providing students with valuable hands-on experience working on large scale software projects and special equipment that is not normally available in a traditional classroom setting. If the main product of the lab is free educational software, then other students across the nation and around the world also benefit from the labs operations. This paper describes one such lab, the Virtual Reality Undergraduate Projects Laboratory, (VRUPL), located at the University of Illinois Chicago. Information is provided describing both the VRUPL lab itself and the educational software it produces, as well as a discussion of the educational benefits provided to both local and remote students.

Categories and Subject Descriptors
K.3.2 [**Computers and Education**]: Computer and Information Science Education – *Computer science education.*
K.3.1 [**Computers and Education**]: Computer Uses in Education – *Computer assisted instruction.*

General Terms
Human Factors, Experimentation.

Keywords
Virtual Reality, Education, Safety, Simulation, Laboratory.

1. PEDAGOGICAL BACKGROUND
Traditional educational methods meet the needs of some students in some subjects, but they do not deliver optimal learning to all students in all subjects. Active participation and hands-on experience greatly enhance traditional methods, but there are certain experiences that are just not possible in the real world. Virtual reality, VR, can provide these experiences safely, as well as addressing the educational needs of certain learning styles.

1.1 Dale Edgar's Cone of Learning

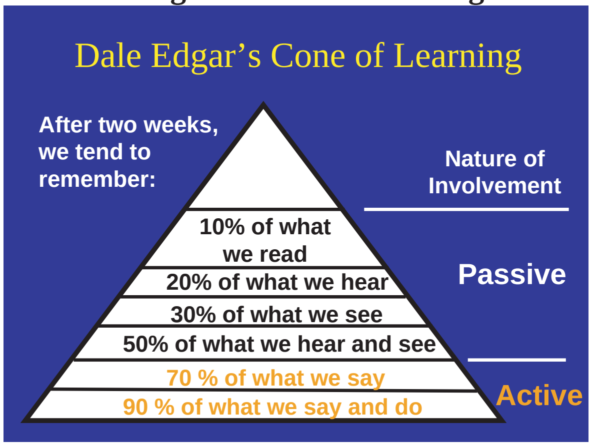


Figure 1 - Dale Edgar's Cone of Learning

Dale Edgar conducted a study in which students were taught using a variety of different teaching mechanisms, and tested two weeks later to see how much they had retained after that time[1]. His results, which are well known in educational circles and which are shown in Figure 1, yield two important conclusions:

1. The more different channels through which a student receives information, the better the information is retained. (Watching a movie is more effective than either hearing words alone or looking at still pictures.)
2. The deeper and more active a student's participation, the better their retention. Doing the real thing is better than watching a simulation, which is still better than merely hearing or reading about it.

VR delivers active participatory experiences that are both aural and visual. This high degree of active simulation is second only to doing the real thing on Dale Edgar's scale of involvement.

1.2 Learning and Teaching Styles
As indicated above, all students learn through a wide variety of different mechanisms: reading, listening to lectures, participating in discussions, working on homework problems, conducting active experimentation, quiet reflection, and watching educational

[1] *SIGCSE Annual Conference*, Norfolk, VA, March 2004.

videos are only a few examples. For any given student and any given educational concept, some of these mechanisms will be much more effective than others. These preferred modes define a student's *learning style*. There are also corresponding *teaching styles*, and when the latter does not match well with the former, it can be difficult for that particular student to learn.

Felder and Silverman addressed learning and teaching styles [2, 3], and developed five dimensions along which they are defined:

- **Visual-Verbal:** Visual learners learn best from pictures, diagrams, videos, and other visual input; Verbal learners prefer reading, lectures, discussion, and other verbal activities.
- **Sequential-Global:** Sequential learners can learn complex subjects step by step, with partial understanding when the subject is partially complete; Global learners need to see the big picture and how all the parts fit together before any of the individual parts make sense, but often get more understanding of the overall subject once all the pieces are in place.
- **Active-Reflective:** Active learners learn best when they can actively participate, in a discussion, experiment, or play; Reflective learners are better able to learn through quiet study, introspection, and reflection.
- **Sensory-Intuitive:** Sensory learners learn best through sensory input, such as sights, sounds, and smells. Intuitive learners are better suited to handle internal concepts, thoughts, and ideas.
- **Inductive-Deductive:** Inductive learners observe phenomenon and then infer the underlying principles that must explain them; Deductive learners start with fundamental theories and then deduce how they apply to practical applications.

Felder and Silverman conclude that teaching methods in engineering typically fail to address the learning styles of many engineering students, who tend to be visual, active, sensory, inductive, and often global, while traditional methods tend to be verbal, passive, intuitive, deductive, and sequential.

VR addresses this gap, by delivering an experience that is highly visual and active, and which gives global learners an opportunity to see the overall picture of the subject in a larger context.

1.3 Experiential Learning

In addition to the benefits of delivering education through multiple delivery channels, and addressing students' optimal learning styles, Kolb found additional benefits to be gained by learning through experience. [4] Someone reading about a house fire or an auto accident in the newspaper, for example, will only remember the details for a short while; Someone who *experienced* the fire or the auto accident (and survived), however, will remember that experience for the rest of their lives.

VR provides the opportunity to deliver educational experiences that would not be possible through any other means, such as exploring the microscopic pores of a catalyst pellet, entering a chemical reactor while it is operating, or surviving a laboratory explosion and repeating the experience in order to ascertain the cause of the explosion. (Note: Virtual experiences will never compare to real experiences, and should not be used as a substitute for the latter when the latter is available. The authors do not promote replacing traditional hands-on experiments with virtual ones, but rather supplementing them with experiences that are too hazardous, inaccessible, or otherwise impossible to achieve without simulation.)

2. THE VRUPL LABORATORY

This section describes the physical and human resources of the VRUPL lab, as well as how the lab operates.

2.1 Physical Resources

Physically the VRUPL lab is quite modest and inexpensive. It occupies two rooms, each of which is the size and configuration of a normal faculty office. The main room has two tables with three personal computers, laser printer, flatbed scanner, and a bookshelf full of relevant computer graphics textbooks and software manuals. The second room is currently used as a library / study room, but will soon be populated with a number of new computers, including both new PCs and some Silicon Graphics O2s. (The existing PCs were purchased some years ago; The SGIs are being moved from general purpose computing labs.)

Special equipment in the VRUPL lab includes five sets of head-mounted displays of various types, a Polhemus electromagnetic head and hand tracker, a Logitech acoustic tracker, CrystalEyes stereoscopic eyewear, and a digital camera.

VRUPL is organized as a satellite to the much larger Electronic Visualization Laboratory, (EVL), which is world-renowned in virtual reality, computer graphics, scientific visualization, (immersive) display technology, and high-speed networking. This arrangement gives VRUPLers access to advanced equipment such as the CAVE™[5], Immersadesks™[6], and tiled displays, while keeping the undergraduates from disturbing the normal operation of graduate research activities.

2.2 Human Resources

The VRUPL lab is directed and managed by the author of this paper. More than 30 undergraduate students and five graduate students have been involved in VRUPL since its inception Currently there are fourteen active VRUPLers, working on nearly a dozen different projects and subprojects. These include seven experienced VRUPLers and seven new students who have just joined the VRUPL lab. One of the experienced VRUPLers is a graduate student who joined VRUPL as an undergraduate; Another will graduate soon, and also plans to continue with VRUPL as he pursues his graduate studies. Several students have chosen to continue working for VRUPL after their graduation and prior to commencing regular employment.

2.3 Lab Operations

VRUPL students work in the lab for one of three major incentives (or combinations thereof) : Class credit, money, or just plain fun. And of course, everyone gets the opportunity to enhance their education, share an experience with other bright energetic minds, and play with all the cool toys. In terms of class credit, some students enroll in CS 398, special topics, and some are involved in VRUPL as an Honors College activity. VRUPL has some funding from the National Science Foundation that is used to provide some hourly student stipends, and VRUPL also gets some REU (Research Experience for Undergraduates) from the EVL. The students working just for fun generally have very full schedules, and do not want to add any additional commitments. Students who want to get paid by VRUPL must generally complete CS 398 first, both to get the necessary training and also to confirm their genuine interest in more than just a paycheck.

As far as training goes, VRUPL is fortunate to have about an equal mix of experienced VRUPLers and new students, so the new people generally learn from the old hands. In addition, the older students are generally being paid, and one of their specific job duties is to teach the new students. VRUPL also tends to attract bright independent self-starters, which helps a lot, because they do not generally require a great deal of training from the lab director. Logistically the director meets with each of the students at lest once a week, generally in groups of two to four students working on the same or related projects, and generally for half-hour to hour meetings. CS 398 students are expected to work on a cohesive project for the duration of the term, and submit a term project report at the end of that time. Paid employees and students working just for fun and experience may have more variety in their activities.

3. PRODUCT DESCRIPTION

3.1 Virtual Lab Accidents

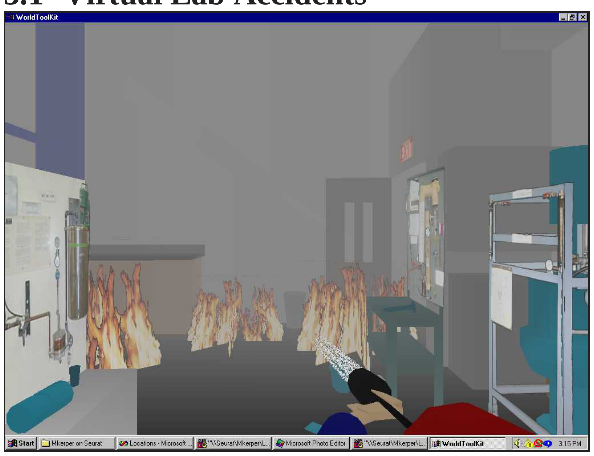


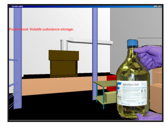
Figure 2 - Extinguishing a Laboratory Fire

Long lists of written safety rules are quickly forgotten, and both students and professionals can quickly become complacent about laboratory safety. Anyone who has ever *experienced* a real lab accident, however, will never forget that experience. The overall goal of this project is to create a series of VR-based laboratory accidents, which will allow laboratory users to experience first hand the consequences of not following proper laboratory safety procedures. Simulations will not be as memorable as real accidents, of course, but they will be much more memorable than written safety rules.

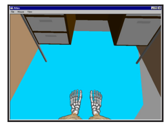
3.1.1 *Accidents Simulated*

Eight lab accident scenarios have been chosen for development, based on their applicability to a wide range of lab environments in educational, research, and professional domains; on their amenability to simulation in a virtual environment; and in particular on the ability to demonstrate the consequences of not following the safety rules properly; as follows:

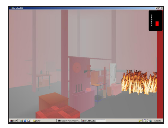
Always wear safety glasses in lab: An accident sprays the user, causing either goopy glasses or blindness (a totally black screen with no recovery.)



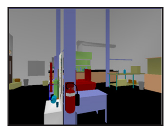
Store Chemicals Properly: The user has a limited time to clean up the lab and put everything away properly, before it explodes.



Always wear proper attire: Improper footwear or the lack of a proper lab coat can have dire consequences in a lab environment, as this user discovered!



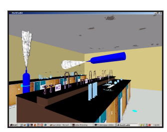
Keep Aisleways Clear: In the event of a fire, a clear aisleway can make the difference between exiting the lab safely or being trapped in a fiery death.



Know the locations of exits and fire extinguishers: When accidents occur, there may not be time to search for these vital items, which may be blocked.

No food or drink allowed in the laboratory: Failure to heed this rule can lead to the ingestion of potentially life-threatening material.

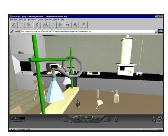
No horseplay allowed in the lab: Even innocent fun can turn deadly in the presence of dangerous equipment, toxic substances, and other hazards.



Securely fasten compressed gas cylinders: Otherwise a broken nozzle can turn the cylinder into a highly dangerous flying torpedo!

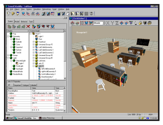
3.1.2 *Platforms Investigated*

One of the research goals of this work is to investigate different development platforms, in order to determine which are most amenable to the development and implementation of this type of educational application. This also gives students the opportunity to explore a variety of cutting-edge software development platforms. Five different platforms have been investigated to date, as follows:

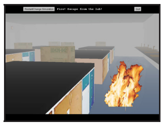


VRML: The VRML platform is popular and platform independent, allowing users to run simulations in their normal web browsers..

WorldToolKit: This C-language toolkit supports multiple hardware platforms and optional devices, but requires installing compiled code.



WorldUp: Provides a graphical development environment interface to WorldToolKit functions. Can be compiled or run in a web plug-in.



Java3D: This package extension to Java provides for 3-D objects, actions, and interactions. Accidents run in a web browser with a plug-in.

Half-Life game engine: Based on a popular game, provides for easy environment building, explosions, fire effects, and user interactions.

3.2 Virtual UIC

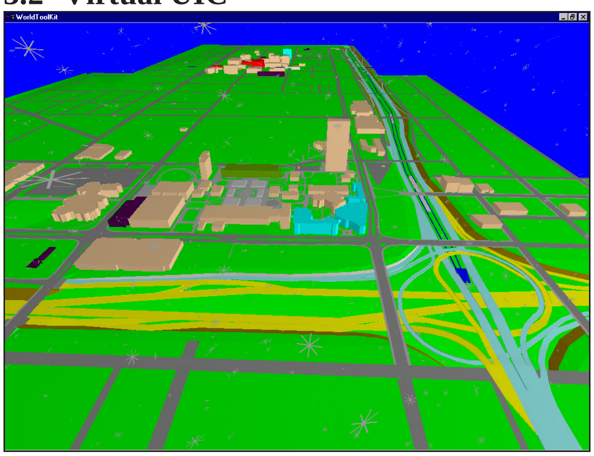


Figure 3 - A Campus Overview of Virtual UIC

Another project area under development in the VRUPL lab is a VR based simulation of the UIC campus, with intentions of eventually modeling many individual buildings. The Office of Facilities Planning and Space Analysis graciously provided 2-D AutoCAD blueprints of the campus and all buildings as a starting point for the modeling involved in this project.

3.2.1 Environments Modeled

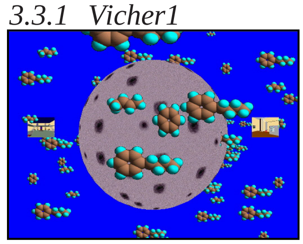
The initial environment modeled was the campus overview, starting from an AutoCAD map of the entire campus, as shown in Figure 3. Each of the building outlines was converted into a separate building object, to enable pop-up display of building names as the mouse cursor rolls over each building. These then were aligned with the model of the grounds, roads, and parking lots, and augmented with models of nearby landmarks such as the interstate expressways and elevated train structures. The ultimate plan is to link the building objects to detailed simulations of individual buildings. The following individual building structures either have been modeled or are in progress:.

- **University Hall -** This 29-story building (w. basement) is the tallest building on campus, and the first one the students tackled. Each floor has a slightly different layout, requiring them to be individually modeled. Students used a digital camera to capture unique decoration features on each floor of the building, and arranged furniture according to its actual placement within the building.
- **Burnham / Adams / Taft Trio -** These three building are interconnected by overhead covered walkways, and were modeled as a set of four related environments (three interiors and the common exterior), with triggers to automatically switch environments as appropriate.
- **Behavioral Science Building -** Easily the most complicated and confusing building on campus, this structure is famous for getting people lost in its winding stairways and convoluted passageways. The simulation is noted by its interactive heads-up map, including direction-finding capabilities to mark the route to any given room in the building upon request.
- **Lecture Centers -** The central feature of east campus, these six lecture centers are each slightly different, and are modeled as six separate interior environments plus a common exterior. The exterior model also includes billboard images of important neighboring buildings (such as University Hall) as navigational landmarks.
- **Douglas / Grant / Lincoln Halls -** This trio of mostly classroom buildings is currently under development, and will closely parallel the Burnham / Adams / Taft trio. A complicating factor for this trio is the presence of special offices and facilities, as opposed to simple rooms full of desks in the pure classrooms.
- **Stevenson Hall -** Another major classroom building.

3.3 Maintenance of VRiChEL Products

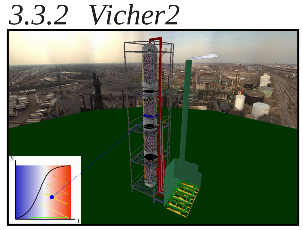
Before the author came to UIC, he ran a similar lab at the University of Michigan entitled VRiChEL - The Virtual Reality in Chemical Engineering Laboratory. VRUPL currently maintains and distributes the following VRiChEL products:

3.3.1 Vicher1



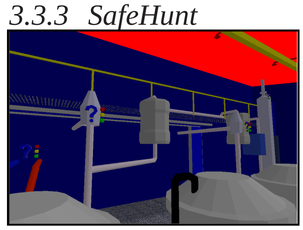
Vicher1 illustrates concepts of heterogeneous catalysis, and common industrial methods for handling slow, medium, and fast rates of catalyst decay. In addition to three different reaction rooms, in which student can both operate and enter into chemical reaction equipment, Vicher1 also includes three microscopic environments in which students can observe catalytic reactions taking place at the molecular level.

3.3.2 Vicher2



Vicher2 is similar to Vicher1, except the subject matter is non-isothermal kinetics, and there are no microscopic areas modeled. One of the educational constructs explored in Vicher2 is to make a tangible connection between the two-dimensional abstract world of plotted mathematical functions and the three-dimensional physically tangible world of the functional equipment, as seen in the image shown here.

3.3.3 SafeHunt



SafeHunt is a safety scavenger hunt, set within a polyether polyol production facility modeled after a real chemical plant. Students must find and activate question marks within the plant, and then evaluate the safety-related scenarios that are presented as either dangerous, cautionary, or safe. Students earn points for correct answers, and feedback is provided for either correct or incorrect responses.

4. EDUCATIONAL BENEFITS

The activities of the VRUPL lab provide strong educational benefits to two major groups of constituents: the students working in VRUPL, and the students who use the products that VRUPL produces. The following sections explain each of these benefits.

4.1 Benefits to VRUPLers

The VRUPL students benefit from the experience of working on large complex projects, above and beyond the scope of anything they might encounter in their normal classroom activities. (Some of the projects have been ongoing for years, with the history being carried forward by the long-term VRUPL members.) Both Dale Edgar's cone of learning and Kolb's work on the educational value of experience would agree that this greatly enhances their overall education. In addition, they get to collaborate with other bright energetic minds both within VRUPL and also within EVL, and they have access to advanced computers and other equipment that cannot be made available to the general undergraduate population.

4.2 Benefits to the International Community

The original VRiChEL products (currently maintained by the VRUPL lab) have been downloaded over 1300 times, to recipients in over 50 different countries around the globe. The virtual lab accidents have now been produced for all eight accident scenarios, on two to five platforms each, for a total of 25 different accident simulations freely available to the international community. The virtual UIC products may not be as universally valuable, but they can be quite useful to students planning to attend UIC from far-away lands. (A large fraction of the UIC student body comes from either India, China, or some other foreign country.)

In addition to the values of participation and experience, VR based educational software is of particular value to visual learners and global learners on Felder and Silverman's dimensions of learning styles. (VR allows global learners to experience educational concepts within a larger context, and to see how all the pieces fit together and interrelate.) This type of educational software is also of benefit to active, sensory, and inductive learners.

4.3 Accessing the Software

All of the software products described in this paper are available free of charge on the VRUPL web site.[7]

5. CONCLUSIONS

This paper has described a student projects laboratory that is relatively simple to set up and run, and which delivers important educational value to two important constituent groups: The students who work and play in the lab, and the students who use the products of the VRUPL lab. Both groups gain from the educational benefits of active participatory involvement and first-hand immersive experience. The software developed is also of particular value to visual global, active, sensory, and inductive learners on the Felder-Silverman dimensions of learning styles.

6. ACKNOWLEDGMENTS

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Opinions expressed are those of the authors and not necessarily those of the Foundation

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