**An Educational Consortium for Teaching Key Concepts to Undergraduates**

This project will focus on using state-of-the-art, three-dimensional computer technology to facilitate moments of learning key concepts in core undergraduate courses. Indiana University (IU) has developed an impressive array of computer technologies for the depiction of three-dimensional imagery, along with substantial technologies to assist doctoral-level research and teaching, housed primarily on its Bloomington (IUB) campus. This project would take one of those technologies and adapt its ability to display an interactive three-dimensional model to the teaching of key concepts ultimately in five disciplines, implementing the teaching modules first on one of the nine regional campuses of IU, Indiana University Northwest (IUN), in Gary, Indiana. After piloting the project in Gary, we would take its technology on to other regional campuses of Indiana University. As the project moves forward, we will enlarge its use from one discipline (pharmacology/nursing) to five disciplines (nursing, finance, environment, mathematics, chemistry), from IUN to other IU regional campuses and eventually other interested universities, both large and small.

**IU's Bloomington's Advanced Visualization Laboratory (AVL)**

Indiana University's Advanced Visualization Lab (AVL) is well positioned to partner with IUN on this project. The AVL currently provides consulting, research support, educational opportunities and hardware and software resources for scientific visualization, virtual reality (VR), and high-end computer graphics. IU Bloomington resources include high-end graphics workstations and projection-based virtual reality devices: a CAVE (advanced immersive virtual reality display) in Bloomington and an ImmersaDesk (two dimensional freestanding display simulating three dimensions) in Indianapolis. A participant in Internet2, Indiana University has a long history of involvement in leading-edge technologies including computer graphics, scientific visualization, networking, and physical science simulations.

IU Bloomington has issued an invitation for subject matter experts, computer scientists, visualization specialists, and interface designers to join in partnership to explore advances in VR and high-performance computing. These partnerships would investigate the application of the new technology to real-world situations, to increasing understanding, productivity, and competitiveness. This project rises to meet IU Bloomington's standards and call for participation. Collaborations using this technology have already begun with IUB and University of Chicago. For example, the *Solar Journey Project* is in the process of developing VR tools to display astrophysical properties of the Sun's journey through space-time. However, more learning tools are needed, particularly ones that are aimed at the undergraduate population.

**AVIDD and Institutional Capability**

In addition to partnership with AVL, IUN is currently collaborating with the Bloomington and Indianapolis campuses of Indiana University on AVIDD (Analyzing, and Visualizing Instrument-Driven Data flows), a new experimental supercomputer, with massive amounts of disk storage and multiple visualization devices. This National Science Foundation-funded project will provide an integrated and coherent way of managing, analyzing and visualizing the vast amounts of data generated by the new generations of large scientific instruments, using very high network bandwidth provided by IU's optical fiber infrastructure. AVIDD's high bandwidth capability includes visualization and data presentation environments that will support collaborative research, distance education, and of special advantage for this proposed project, high quality 3D visualization. It is our intention to leverage the visualization possibilities of the AVIDD project to teach key concepts ultimately in five disciplines. An 8'x6' visualization display wall that will be installed on campus as part of AVIDD for teaching and distributed education will be a central component of this project. This display concept will be modified using off-the-shelf products to construct a semi-portable display similar to a rear projection television.

**Assumptions of this project**

There are five basic underlying assumptions to this project: (1) Every discipline has key concepts (2) Those concepts may be taught in a way that maximizes drama and student engagement with subject matter (3) Advanced technologies are underutilized for delivery of instruction on the undergraduate level (4) The model we describe can be replicated in other states with well-equipped research resources and low-tech regional campuses and (5) Underprepared students will learn key concepts more efficiently using three dimensional representation. This technology will facilitate learning among the post-MTV, videogame-oriented populations which all US colleges and universities currently serve.

We have found that the current generation of students may be visually sophisticated, but a significant segment are less skilled readers and rarely engage in reading. A better strategy for learning for this generation may be to offer the opportunity to interact with a visual concept, and then engage in conversation about what they have seen and done. We believe that Gardner's Theory of Multiple Intelligences is correct. Howard Gardner of Harvard University defines intelligence as "the capacity to solve problems or to fashion products that are valued in one or more cultural settings." His pluralistic view of intelligence suggests that all people possess at least seven different intelligences, which operate in varying degrees depending upon each person's individual profile of intelligences. The seven intelligences identified by Gardner include linguistic intelligence, logical-mathematical intelligence, spatial intelligence, bodily-kinesthetic intelligence, musical intelligence, interpersonal intelligence, and intrapersonal intelligence. (Howard Gardner, *Frames of Mind: The Theory of Multiple Intelligences.* New York: Basic, 1983)

Generally, education depends heavily on a student's linguistic or logical-mathematical intelligence, while this technological/pedagogical innovation taps into the three-dimensional, spatial intelligence. If today's college and university students are not receiving information effectively through reading words on the printed page and they cannot picture a concept based on those words, then the supplemental strategy we propose will eliminate that barrier to understanding. IUN's student population will be a particularly good cohort for testing modules because IUN's students are an urban, academically underprepared group drawn from the economically disadvantaged communities IUN serves. Other regional campuses of the Indiana University System will provide rural and affluent cohorts for comparison. In addition, we see this technology – and these teaching strategies -- not only useful at the undergraduate, university level, but for community college and high school populations as well. The potential for application at the graduate level, particularly in medical schools, is similarly attractive.

We think that if a student could actually see molecular bonding taking place, an atom split, a mathematical concept visually displayed, all in three dimensions, in a way that was interactive, then there is a greater likelihood of understanding. It is expected that the visual representations that this technology and the teaching modules that would accompany it, would produce a "light bulb" experience. Voice or keyboard data input changes the 3-D representation, and makes abstract equations real and comprehensible. The technology translates the abstract into the visual, in a way that the concept is made palpable, and manipulable through data input. The three dimensional representations would engage the student in the key concept directly. For the underprepared minority or first generation college student in science or mathematics, who has difficulty in grasping key concepts, this project will provide one more tool for an instructor to add to his/her arsenal of instruction to help these students understand key course concepts.

**Examples of use:**

<u>Finance</u> – "One of the hardest concepts for students to conceive is how the current stock prices are determined. Theoretically, stock prices should reflect discounted dividends plus future growths. This is a concept where you need 3-dimensional visualization. This technology enables students to visualize the stock price scenarios when the assumptions of dividends and growth vary."

Bala G. Arshanapalli Ph.D. Endowed Professor of Business

<u>Pharmacology</u> – "I believe that Drug Metabolism (Cytochrome P450) would be a perfect fit for the AVIDD display technology. It is a concept in pharmacology that is difficult for students to grasp, but once they master the concept it opens the door to a firm understanding of drugs. I am very excited about the potential that this technology can bring to pharmacology."

Marcia S. Mulcahey MSN, RN, CS, ANP

<u>Mathematics</u> –" Multi-variate calculus demands visualization of surfaces and intersection of surfaces in three dimensions in space in order to understand the concepts of partial derivatives, directional derivatives, gradients, multiple integrals, the use of multiple integrals to find volumes described in terms of surfaces, line and surface integrals, and Stoke's and Green's Theorems. Most mathematicians can see these surfaces in their minds. This is a skill not shared by most students. Currently we try to have students use programs like *Mathematica* to assist in developing this skill. 3D imaging would be a better tool to accomplish these goals. We would work with programmers to develop these tools.

In an Euclidean Geometry course, 3D imaging would be used to illustrate theorems. We would also like to introduce our students to Euclidean Geometry in n space. Three-dimensional surfaces in 4-D space could be viewed as projections into 3-D space. This would open up an exciting new way of thinking for our students."

H. L. Wyzinski, Chair, Department of Mathematics and Actuarial Science

**What it is:**

The technology we propose to use projects an apparently 3-D scene on a two-dimensional screen that simulate spatial depth and requires an inexpensive special viewing device (paper glasses with a green and red tinted plastic lens). The display is similar in size and shape to a 54-inch or 70-inch projection television, that is interactive (you can change its dimensions through voice and keyboard input), that seems to exist in space, that rotates on command, and that move elements against one another. It is a dynamic 3-D virtual tool for representation, but less expensive than a true holographic projection. The imagery it presents is dramatic, and as a consequence, we propose to use this technology sparingly in instruction – to reserve its dramatic impact for the presentation of key concepts. We consider the modules to be developed as part of a lab component of the courses they will enhance.

**What it requires:**

A Key Concepts Laboratory will be built on the campus of participating partners. Off the shelf components will be used to lower costs. Because the programming will be done in C++, VRML, or similar widely used visual programming language and the operating system will be Linux (open source, non-proprietary software) or BSD (Berkley Standard Unix), the cost of implementing the technology on other campuses will not be prohibitive. Thus this project will provide a reasonably priced solution that can be adopted widely. CD-ROM or DVD technology will be used to share and disseminate instructional modules, without respect for national boundaries. Authors of teaching modules developed for the Educational Consortium for Teaching Concepts to Undergraduates may donate their module to a library of teaching modules, in exchange for membership to a lending library of similar modules. The deposit of one teaching module into the library will entitle the author's institution to use library modules without cost.

**Summary of Objectives of the Project:**

1. Identify key concepts in ultimately five disciplines that are amenable to visualization.
2. Design and develop a low cost, replicable key concept laboratory using technology developed in Bloomington and repurposed at IUN.
3. Identify and recruit academic partners for module development.
4. Improve student grasp of key concepts in five undergraduate courses through implementation of this technology.
5. Identify potential business partners to develop a commercial display product.

**Project Partners**

IU Bloomington - Advanced Visualization Lab: The Advanced Visualization Lab brings the AVIDD concept from an NSF grant complete with a working hardware and software model that can be modified to reduce cost and target this specific application of a visual pedagogy.

IU - School of Informatics: The School of Informatics New Media program may provide graduate students who could learn the visual display technologies by working on class projects that result in creation of key concept modules. This would be a longer-term outcome of initial work started by AVL programmers and then brought into the mainstream class work of the School of Informatics.

IU – School of Library and Information Science: The School of Library and Information Science (SLIS) currently has several virtual world projects underway. While this particular grant is not as intensive as virtual worlds, the basic underpinnings could yield a collaborative and review process that would strengthen the development process. In addition, The SLIS may be a natural repository for the key concept module collection.

**Outcomes:** Outcomes will be measured by pre and post testing of key concepts. Student retention will be tracked to determine whether teaching key concepts in this way improves retention. Part of the instructional design task will be to develop a measurement model independent enough to report results. The number of modules developed and deposited in the project's electronic library will be another indicator of the project's success.

**External Evaluator:** We propose to invite a faculty member from Bloomington or Indianapolis who is familiar with instructional technology to design an appropriate evaluation for this project beginning in the first year. Evaluation will be both formative and summative. The evaluator will write interim reports at the end of the first two years, and a final report at the end of the third year.

**Timeline:**

First year

Identify initial faculty partners, and key concepts for visual content creation.
Identify the base visualization program that will be used.
Identify off-the-shelf hardware configuration.
Hire programmers and visual designers.
Two discipline modules fully developed as a pilot and taught at one institution (IUN).

Second year

Expand modules under development to three disciplines.
Four discipline modules fully developed and used in instruction.
Expand program to another regional campus for evaluation.

Third year

Expand modules under development to five disciplines.
Six discipline modules fully developed and used in instruction.

**About Indiana University and Indiana University Northwest**

Indiana University is one of the oldest state universities in the Midwest, and also one of the largest universities in the United States, with more than 110,000 students, faculty and staff on eight campuses. IU has a growing national and international reputation in the areas of information technology (IT) and advanced networking. IU's extensive IT environment is made up of high performance computing resources, facilities for massive data storage, and advanced visualization laboratories that enable leading scientists to visualize, analyze and store vast amounts of data and information. Indiana University Northwest serves seven northwest counties of Indiana, offering more than seventy degree and certificate programs in liberal and professional studies. The IU Northwest student body includes a high percentage of students from traditionally under-represented groups. The Educational Consortium for Teaching Key Concepts to Undergraduates will better prepare these students to become members of the twenty first century population of technology empowered citizens.

**Definitions:**

VIRTUAL REALITY:

Virtual reality is the simulation of a real or imagined environment that can be experienced visually in the three dimensions of width, height, and depth and that may additionally provide an interactive experience visually in full real-time motion with sound and possibly with tactile and other forms of feedback. The simplest form of virtual reality is a 3-D image that can be explored interactively at a personal computer, usually by manipulating keys or the mouse so that the content of the image moves in some direction or zooms in or out. Most of these images require installing a plug-in for your browser. As the images become larger and interactive controls more complex, the perception of "reality" increases. More sophisticated efforts involve such approaches as wrap-around display screens, actual rooms augmented with wearable computers, and haptics joystick devices that let you feel the display images.

Virtual reality can be divided into:

a) The simulation of real environments such as the interior of a building or a spaceship often with the purpose of training or education.

b) The development of an imagined environment, typically for a game or educational adventure.

Popular products for creating virtual reality effects on personal computers include Bryce, Extreme 3D, Ray Dream Studio, trueSpace, 3D Studio MAX, and Visual Reality

VRML (Virtual Reality Modeling Language) is a language for describing three-dimensional (3-D) image sequences and possible user interactions to go with them. The Virtual Reality Modeling Language (VRML) allows the creator to specify images and the rules for their display and interaction using textual language statements. Using VRML, you can build a sequence of visual images into Web settings with which a user can interact by viewing, moving, rotating, and otherwise interacting with an apparently 3-D scene. For example, you can view a room and use controls to move the room, as you would experience it if you were walking through it in real space.

HOLOGRAM:

A hologram (pronounced HOL-o-gram) is a three-dimensional image, created with photographic projection. The term is taken from the Greek words holos (whole) and gramma (message). Unlike 3-D or virtual reality on a two-dimensional computer display, a hologram is a truly three-dimensional and free-standing image that does not simulate spatial depth or require a special viewing device. Theoretically, holograms could someday be transmitted electronically to a special display device in your home and business.

Dennis Gabor developed the theory of holography in 1947. The development of laser technology made holography possible.