

Discovery-Based Learning Engineering Classroom

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Abstract

Engineering design, optimization, and analysis practice in the 21st century is performed using complex computer models and graphical visualization of the results. Engineering education must also incorporate teaching and use of computer models for enhancing the depth and breadth of student learning. Today, we use a computer center to provide access to computers and educate engineering students to understand and apply engineering software such as AutoCAD, SolidWorks, Matlab, and Ansys, to name a few. Virtual environments provide the sensory experience of being in a computer generated, simulated space. They have potential uses in applications ranging from education and training to design and prototyping. An immersive environment simulates a virtual environment by “imbedding” the learner in an environment where “discovery” becomes part of learning. Therefore, we have chosen the term discovery learning where professors and students are enabled to “explore” through immersion, simulation, and animation.

This article discusses the implementation of a Discovery Based Learning Classroom for Engineering courses. The Discovery-based Learning Center is a sophisticated viewing facility, theater, and lecture room for interactive real-time simulations of virtual models, environments, and processes. The center provides a unique laboratory/classroom environment for immersive interaction with models, environments, data, and processes in engineering and the sciences. The center merges teaching and research activities into a powerful discovery environment in which faculty and students share a problem-solving tool for exploration of any subject using methods that are impossible in a physical laboratory. The first course that will be implemented in the classroom is our freshman engineering problem solving/programming course using Matlab.

The different phases of design and implementation of this very sophisticated classroom as well as the first semester teaching and learning experiences in this new environment are described in this article.

Background & Motivation

The College of Engineering at the University of Rhode Island introduced a freshman engineering experience in 1996 consisting of a 1-credit semester course covering the foundations of engineering during the fall semester and a 2-credit engineering problem solving/programming course during the spring semester. This change was made for all eight engineering programs such that all engineering students would experience a common curriculum during the first year. Many benefits have resulted from this change over the past decade including the following highlights:

- Retention of engineering students from the freshman year to the sophomore year increased from ~60% to ~72% (see figure 1).
- Engineering majors can more easily switch from their entering engineering major to a new engineering major starting in their sophomore year.
- The percentage of undeclared engineering majors during the freshman year increased since students didn't have to commit to a major until the start of their sophomore year.

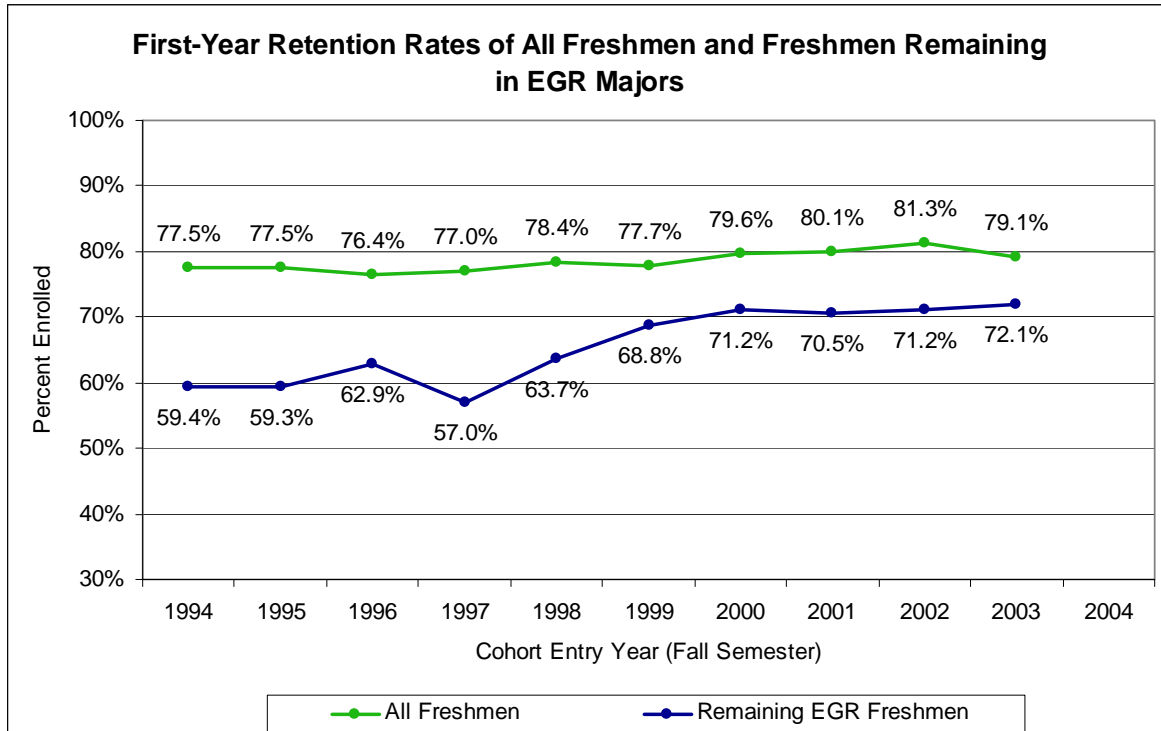


Figure 1. Retention rate of URI freshmen (all majors vs. engineering majors)

However, there remains a gap of 7-8% between retention in engineering vs. retention for the University. The University has been exploring strategies to increase the retention and graduation rates for all students at the university. The college of engineering is also exploring strategies for increasing retention and student learning outcomes as well as engineering graduation rates. One of the pedagogical strategies that appears to have positive outcomes with respect to student learning and retention is problem-based (or discovery-based) learning

A funding opportunity in 2006 through the Champlin Foundations presented itself. We prepared a proposal to transform a part of our general computing laboratory for engineering students to a high-technology classroom to allow for the faculty to experiment with discovery-based learning and an immersive environment in appropriate engineering courses. We were successful in our proposal to the Champlin Foundations which provided \$110,000 for acquisition of the hardware, software, and multimedia technologies for the classroom. The College of Engineering committed its own operational funds to renovate the space for the new classroom, approximately \$80,000.

Initial Vision for the Classroom

The Discovery-based Learning Center was envisioned to be a sophisticated viewing facility, theater, and lecture room for life-size interactive real-time simulations of virtual models, environments, and processes. The center would provide a unique laboratory/classroom environment for immersive interaction with models, environments, data, and processes in engineering and the sciences. The center would merge teaching and research activities into a powerful discovery environment in which faculty and students

share a problem-solving tool for exploration of any subject using methods that are impossible in a physical laboratory. For example, imagine riding on a cluster of atoms through a microchannel or flying through a jet engine. The center would also provide a communications medium to foster collaboration and networking that would be utilized by our students, faculty, and administration to improve the academic quality of our programs in engineering, science, business, and information access, to mention just a few.

The Discovery Center would enable our students to experience simulated environments and processes much as we experience the world around us. Visual computing capabilities of the center will let students “see” their data. The visual power of the classroom enhanced with audio provides a perceptual experience allowing one to tap into natural motor skills and physical senses to expand depths of understanding. The center would provide no constraints to a person’s visual system. It would provide an environment similar to natural vision.^{i ii}

For example, our engineering students currently build a mini-Baja vehicle for national competitions, a process that normally takes nine months to complete because many of the problems in the design are discovered during vehicle manufacturing. With the availability of the Discovery Center, students would view large “wrap-around” imagery from inside physical mock-ups of the vehicle or cab, while manipulating actual vehicle controls. The student’s design project would be test driven before a prototype is ever built. Students could fly through a jet engine or follow a *Borrelia burgdorferi* (the spirochetal bacteria that cause Lyme disease) from the glands of a tick through a microchannel (research currently being done as part of our NSF funded PIRE grant).

The Discovery Center was also envisioned to provide a group experience encouraging collaboration and interaction among individuals in many fields (e.g., scientists, engineers, designers, artists, architects, and business planners). The center would change and enhance existing processes for multimedia delivery. It would increase efficiency in presenting data, information, and course content. It would allow us to tap into collaborative and concurrent learning.

The Discovery Center would serve as a multi-use, inter-departmental, and inter-college resource. It would excite, motivate, and attract students, faculty, and administrators (for example, a walk through of the URI campus in the year 2020). Immediate applications of the Discovery Center include: engineering design courses; manufacturing reviews; architectural and engineering walkthroughs; collaborative engineering science courses (e.g., fluid dynamics); business data visualization and decision support; marketing, public relations, recruiting; virtual heritage, the arts; education and training; scientific visualization; solids modeling; and biomedical simulation.

The Discovery Center was proposed to support engineering courses throughout the curriculum as well as the freshman year experience. The foundations of engineering freshman courses (EGR 105 and 106) would use the facility to introduce different disciplines of engineering to students through virtual tours of the disciplines, designs, and concepts. Approximately 1000 engineering students alone will be served by the Discovery Center. The faculty would use the center for teaching, learning, and research and development of new curricula.

Discovery-Based Learning

The concept of the discovery- or problem-based learning has been extensively researched and reported in the literature.^{iii iv v vi vii viii ix} Svaery and Duffey provide a list of eight instructional principals to guide the teaching in and design of a learning environment for discovery-based learning as follows:

1. *Anchor all learning activities to a larger task or problem. That is, learning must have a purpose beyond, "It is assigned".*
2. *Support the learner in developing ownership for the overall problem or task.*
3. *Design an authentic task.*
4. *Design the task and the learning environment to reflect the complexity of the environment they should be able to function in at the end of learning.*
5. *Give the learner ownership of the process used to develop a solution.*
6. *Design the learning environment to support and challenge the learner's thinking.*
7. *Encourage testing ideas against alternative views and alternative contexts.*
8. *Provide opportunity for and support reflection on both the content learned and the learning process.*

The implementation of our discovery-based learning classroom, the technologies, and its environment are driven by the above instructional principals. The environment is designed to facilitate problem-based teaching and learning.

Design and Implementation

The design of the classroom space and its technological configuration was a process involving many constituencies including the project principal investigator, the dean of engineering, engineering computer center staff, the freshman engineering courses coordinator, facilities project manager, an outside architectural firm, other faculty and staff.

The design process began by establishing specifications and requirements for the classroom with the proposed vision for the classroom driving critical decision making on the project. The initial rear of the envelope configuration of the classroom is shown in figure 2. This was the initial concept for the classroom.

The initial concept was design around three very large projections screens, three high-lumen high-resolution projectors connected to the instructor station (with three large LCD screens), 24 student seats and computer stations with dual large LCD screens. This environment required that the professors design their teaching materials to take advantage of the three screens to achieve the vision of the classroom. Many of the existing engineering courses would have to be converted from a lecture format to a problem-based learning format to take advantage of this classroom.

The location selected for the project was an engineering student computer center. An existing room had to be expanded to accommodate 30 seats in the new classroom as well as to provide space for the technologies in the classroom.

An architectural firm was hired to create the actual drawings for implementation of the classroom. After the first few meetings with the architectural firm, a visualization of the classroom was created which is shown in figure 3. This concept was created based on a discussion of having students work in teams on the problems proposed during instruction.

While this initial concept was very attractive it posed many challenges with respect to the visual and multimedia environment that would be surrounding the students.

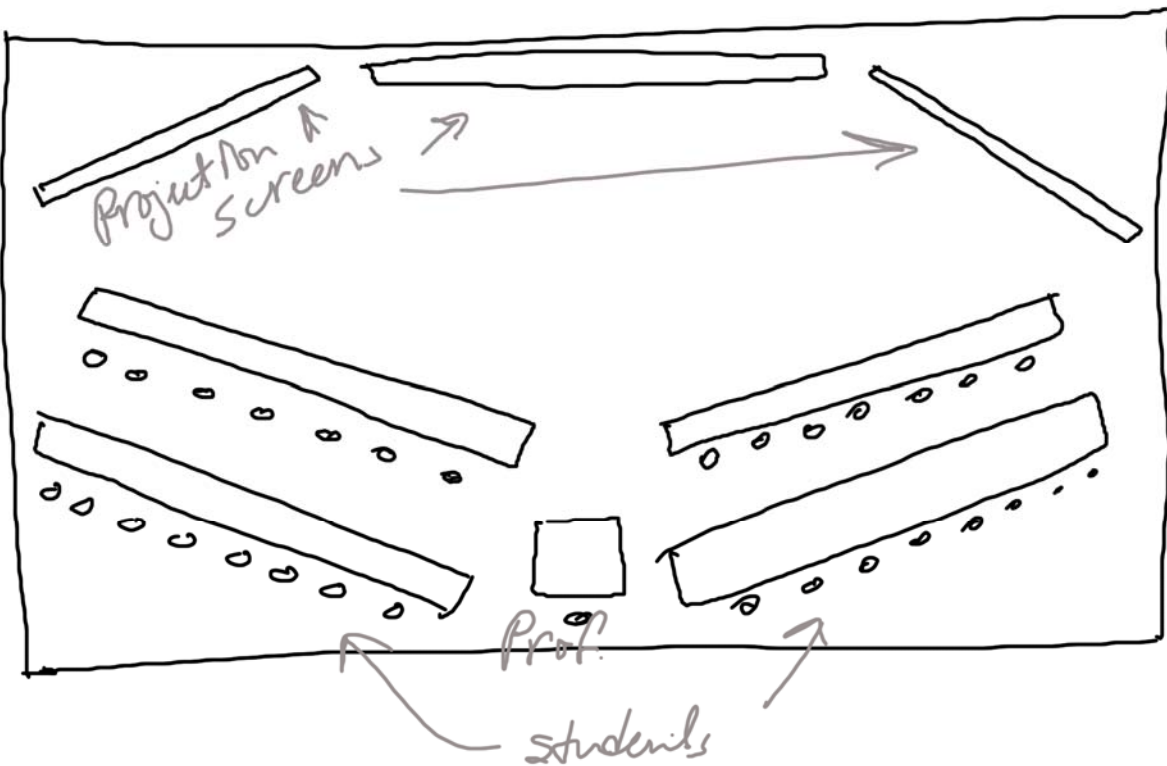


Figure 2. Initial sketch of the Discovery-Based Learning classroom configuration.

The technology environment for the professor

The professor in this classroom must be able to display a wide range of factual, mathematical, visual, simulation-based, experimental-based information and knowledge. The traditional methods of “chalk and talk” are also needed on certain occasions. A majority of the time in the classroom the students will be working in teams of 2 to 4 on problems posed by the professor. Quizzes and some homework assignments will be interactive and completed during class time.

This classroom will use computers as the method of presenting information and problems to the students. The students will be using a range of engineering computer tools such as Matlab, Mathematica, Maple, Ansys, Autocad, Solidworks, Cosmos, and Comsol.

The professor must also be able to control student’s workstations views by allowing them to use various software or disabling their workstations to get their attention for the lecture and classroom interaction.

To maximize the visual impact of the room, we decided on eight large screen LCD monitors (52” in diagonal dimension) mounted around the classroom. The LCD monitors are paired and duplicate two of the three screens on the instructor podium.

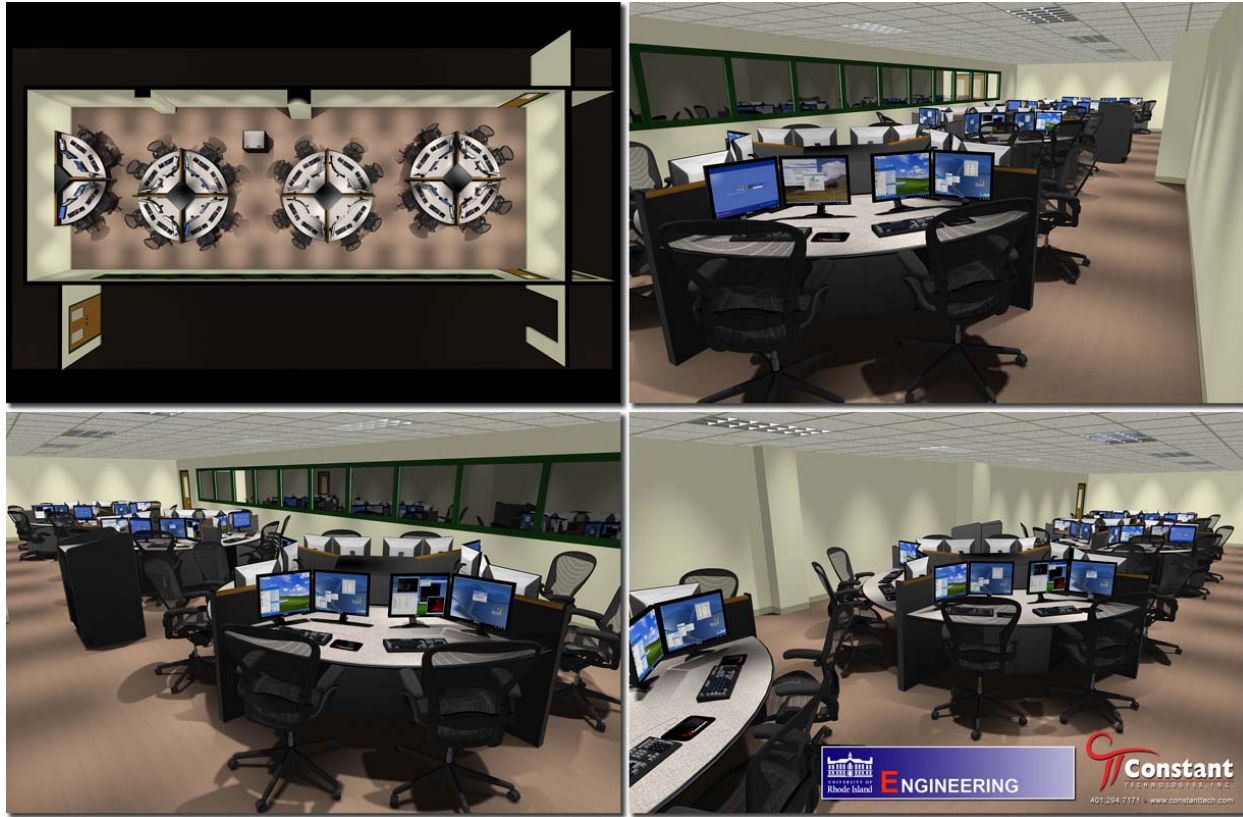


Figure 3. Preliminary design concept for the Discovery-Based Learning classroom.

We also designed the room to have four projectors and four projector screens (two on each end of the rectangular classroom). Each projector screen will cover two of the flat screen LCD monitors when in use. Therefore, the visual system in the room can be operated in one of three modes:

1. Four projectors
2. Two projectors and four LCD monitors
3. Eight LCD monitors

The instructor station is an Intel Quadcore PC with a quad-port video board, 1 terabyte of disk storage, and 4 gigabytes of memory. The instructor station is also equipped with two WACOM pen screens allowing the instructor to write on the computer screen. We chose the Synchroneyes software to control the student workstations. With this software the instructor can broadcast their screen(s) to all student screens or project any student's screen to their own screen.

The technology environment for the students

The technology environment for the students consists of Dualcore PC with 4 gigabytes of memory and 250 gigabytes of disk storage and dual large HD LCD monitors. This environment is similar to the computing environment used in most engineering companies. The dual screens on the student's desktop allows them to view instructional information on one screen while working in a problem solving environment on the other screen.

Student stations may be “blanked” by the professor through Synchroneyes software during lecture so that the students are not distracted by checking e-mail, surfing the web, or playing games on the computer. The instructor will authorize access by the students to software relevant for the course.

Implementation and Current Status

We have now almost completed the implementation of this classroom. The projection systems are being installed this semester and some of the large LCD monitors are installed and being used. We are using this classroom for teaching our second semester freshman engineering course which is our programming/problem solving course. Eight engineering professors and over 300 engineering freshman and sophomore students are using the classroom during the spring semester. The classroom is used as a computer laboratory by all engineering students when it is not in use as a classroom.

A typical classroom session may include some lecture information by the professor including some discussion of the problem of the day that would be viewed on one of the two screens and/or the classroom projector or LCD monitors. The professor can use both monitors to display a photo (or video) of the system, device, or phenomenon while covering the theoretical and mathematical model principles on the other screen.

Outcomes Assessment

We will be measuring the impact of this new classroom and changes in pedagogy for courses offered in this classroom versus courses taught in a traditional format. We have collected a significant amount of historical data for the freshman engineering problem solving course in the past. We will be collecting comparative data for assessment of student learning outcomes. This information and results will be reported in future publications.

Conclusion

The design and implementation of this classroom has been both an exciting and challenging experience. We have stretched the limits of some the technologies for use in a classroom; for example, the number of visual displays, the distances for transmission high definition digital signals from the computer source to the screens, etc.

The response by professors and students has been very positive. Some faculty will be using all of the technology available to them as they change their instructional techniques while some will probably use only the basic features of the classroom. One workshop has already been offered for faculty and additional workshops are planned during the spring semester for faculty to maximize their use of this classroom.

Many students do not have dual monitors on their dorm or home computer systems (or laptops) but observations of classes in sessions indicate that they very quickly expand their work space from one screen to using both screens. Their adoption of this technology seems to come naturally by observing their peers. No effort is needed by the professor to encourage them to use the expanded workspace available to them. Their comments have been very positive.

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Biographical Information

Dr. Bahram Nassersharif is Professor of Mechanical Engineering and Applied Mechanics at the University of Rhode Island (URI). He served as the Dean of the College of Engineering at URI from 2003 to 2007. Prior to coming to URI, he was Department Head of the Mechanical Engineering Department at New Mexico State University and Professor of Mechanical Engineering from 1997 through 2003. At New Mexico State University he was also the director of the graduate distance education programs in the college of engineering and Director of the University's \$1.4-million Title V grant funded by the US Department of Education. From 1991 to 1997, he was the Director of the National Supercomputing Center for Energy and the Environment and Professor of Mechanical Engineering at the University of Nevada Las Vegas. He was the founding director of the Texas A&M University Supercomputing Center and Assistant Professor of Nuclear Engineering and Computer Science at Texas A&M from 1986 through 1991. Prior to Texas A&M, Dr. Nassersharif was a scientific staff member at Los Alamos National Laboratory. In 1988, he was a recipient of the National Science Foundation Presidential Young Investigator Award.

Dr. Nassersharif's research activities have been concentrated in the area of nuclear system design, space-based nuclear systems, automated diagnostics, intelligent design, and high-performance computing. Since 1986, he has received over \$14 million in research funding support from the NSF, US DOE, US DoD, US DoEd Air Force Systems Command, Air Force Weapons Laboratory, Los Alamos National Laboratory, Sandia National Laboratories, US EPA, US NRC, US DOC, Cray Research, NASA, and the Boeing Company.

He is the author and co-author of over 100 technical publications and presentations, and lectured internationally on high-performance computing. He is an elected Fellow of the American Association for the Advancement of Science. He is an active member of several other professional societies including the ASEE, ANS, ASME, IEEE, ACM, AAAI, and SIAM. He has been active in professional society

activities as technical session organizer, conference co-organizer, and reviewer. His professional experience also includes consulting services for industrial and government agencies. He holds a Ph.D. in Nuclear Engineering and a B.S. in Mathematics both from the Oregon State University.

Dr. Nassersharif has been an active participant in NSF Advance program both at New Mexico State University and at the University of Rhode Island. He is the recipient of an NSF Advance recognition award from New Mexico State University and currently serves on the NSF Advance Internal Advisory Council at the University of Rhode Island.

Dr. Nassersharif has been a member of ASEE since 1987. He has been active with ASEE both as a member and by participating in regional and national conferences and served as a reviewer for the Gulf-Southwest conference in 2000. He served as the New England Section chair organizing the ASEE regional conference which was held April 20-21, 2007 at URI. He is currently the ASEE Campus Representative at URI.