Virtual Classroom for Teaching the Economics of Engineering Design

Janis P. Terpenny[1], Kimberly Sward[1], William G. Sullivan[2]
University of Massachusetts at Amherst[1]/
Virginia Polytechnic Institute and State University[2]

Abstract

As decision-makers, engineers must be knowledgeable and competent in multiple aspects of design. Engineering is more than a problem solving activity focusing on simply the expected performance of designed artifacts. Consideration must also be given to the economic consequences of design decisions on life-cycle issues. A major challenge to undergraduate engineering education is to increase student competency in the economic elements that are such a critical part of the engineering process. Many believe that success in this endeavor requires new methods and materials that actively engage students in learning, are more closely aligned with engineering decision-making, and include real-world problems with industry involvement. The objective of this paper is to report on an experiment that has been conducted to determine whether a virtual classroom environment, developed to address these needs, will improve student proficiency in the economic principles of engineering design.

This paper examines the implementation of the virtual classroom for the economics of engineering design, including modularized course notes, software, materials for on-line testing/assessment, and collaboration with industry through team projects. In addition, the paper examines the role of the virtual classroom in today's classroom and its potential for future use. Assessment results and discussion on key questions related to the efficacy of web-based materials in education in general are also included.

I. Introduction

The application of computer based learning as a supplement to classroom instruction is still in many ways in its infancy. Many key questions have yet to be answered; such as is computer-aided learning a replacement for some classroom time, does it favor one type of learning style over another, and how do developers effectively display concepts and ideas in ways that get the students' attention. These questions become of a greater concern as our society becomes more technologically advanced.

The conveying and dissemination of information is key in any learning experience. If the way in which this can be done is expanded to include new media, more students can be reached and a larger portion of the population educated. In addition, new methods of communicating ideas and educating may enhance the learning experience for different styles or types of learners.

With the expansion of Internet use, many doors for education and collaboration have been opened. This paper looks at, in specific, the use of a virtual classroom for economics of engineering design to be used in conjunction with university courses at Virginia Polytechnic Institute and State University (Virginia Tech) and the University of Massachusetts at Amherst (UMASS) and that was developed in collaboration with General Electric, and funded by the National Science Foundation. The virtual classroom provides the basic introduction to economics for engineers and also serves as a continuing resource for undergraduates and for practicing professionals.

This paper will examine the implementation of this project and the technology and ideas behind it. In particular, it will look at the motivation behind and the types of tools developed and used in the virtual classroom. Finally, it will examine the role of the virtual classroom in today's classroom and its potential for future use. The final objective of this paper is to convey results of an experiment to determine whether a virtual classroom environment will improve proficiency in the economic principles of engineering design and its design process.

II. The conveying of information online and web-site design

The goal of any user interface or technology is to maximize the perceived usefulness and the ease of its use[1] (See Figure 1). How easy a system is perceived to be used will directly influence how easy it is to use and vice-versa. In order to get a system that would be actively used by students, researchers, and industry, its content and use had to be easily accessible and somewhat intuitive. It is important to utilize the advantages of this medium to its fullest extent while minimizing the disadvantages. With these concepts in mind, several different design features of the virtual classroom were studied. The classroom, itself, is divided up into many sub-modules, which tackle specific areas of economic design and related concepts. This allows for clarity of presentation and a logical organization of topics. The design features in the modules were examined for the optimal way in which to present different information.
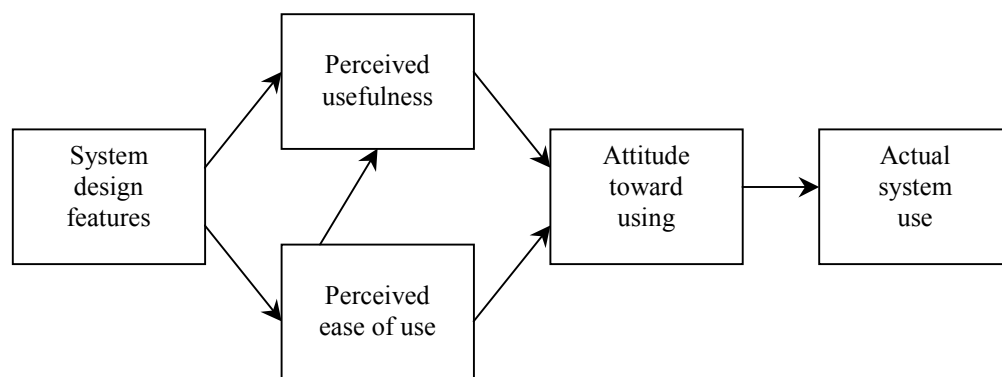
Figure 1. A path analytic model for technology acceptance (from Gillan)

Eye-tracking studies of online materials have shown that users do not read online material in the same conventional manner as that of material printed upon paper. In fact, there is some indication that reading from computer screens is about 25% slower than reading from paper. First and foremost there are some important differences between a computer screen and a sheet of paper or even a blackboard. As of 1997, the average high-end monitor available for commercial use on a computer had about 110 dpi or dots per inch of resolution. This is significantly less than a piece of paper. As quality and technology evolves this will be less of an issue but it is something to bear in mind while designing web content for today's classroom resources.

This difference in resolution can cause eyestrain in users unused to monitor reading. Instead users tend to read highlighted and bulleted text, skimming the rest of the material. Readers generally focus upon text and then upon graphics and tend to read articles and information shallowly with selected more in-depth areas. This requires text to be highly scannable but still have a great deal of content. A recent study showed that 79% of test users scanned every page they came across and only 16% read every word. To combat this tendency a scannable format was used with our web pages. This includes the use of highlighted words, sub-headings, and bulleted lists. Concise text was also used where possible to aid in clarity.[2,3,4]

In addition, it is desirable to make the site as useable to as many students as possible. Often due to the limited nature of HTML and other web formatting tools, scientific equations are embedded into web documents as GIF files or image files of some other sort. The main problem with this practice is that as an image file these equations are unreadable to content readers often employed by the disabled. Therefore, wherever possible in the virtual classroom, equations were written out as well as displayed in order to make the entire site more readable and useable.[5,6]

III. Overall Design of the Virtual Classroom

There is also the logical question of how the page will be navigated and arranged. Many subtopics and areas needed to be developed within its content. This included topics such as industrial problems in collaboration with industry to individual topics areas with quizzes, FAQ's, and overall content review. For this reason the classroom was broken up into a series of related modules. They are as follows: The Business/Engineering Environment, Principles of Design ad Systems Analysis, Cost Estimating Techniques, Time Value of Money and Comparison of Alternatives, Current Industrial Problems, and Consideration of Risk and Uncertainty.

Macromedia's Dreamweaver[7] was used to create the overall content of the classroom. It was selected for its ease of use, dynamic HTML capabilities, and its ability to easily create frames and import HTML from other media including Microsoft Word. For the interactive quizzes, Macromedia's Coursebuilder[8] addition to Dreamweaver was used. This software works with Dreamweaver and creates scripts that allow for easy creation of multiple types of quizzes, choice of button controls, timers, feedback mechanisms, and other quiz related interactions. This

software also includes Jpegs and GIFs for buttons and other quiz features. Unlike some other software available for interactive classrooms, the material produced with Macromedia products is accessible to all who visit the web site. There is no paid fee to view materials. This was an important feature in its selection for use, because the virtual classroom for engineering economics was designed to be an open resource that was available to many universities and industry practitioners.

The virtual classroom was designed to have a consistent feel from the initial entrance at its front page to all subsequent pages thereafter. Refer to Figure 2 for an example of the home page of the Virtual Classroom.
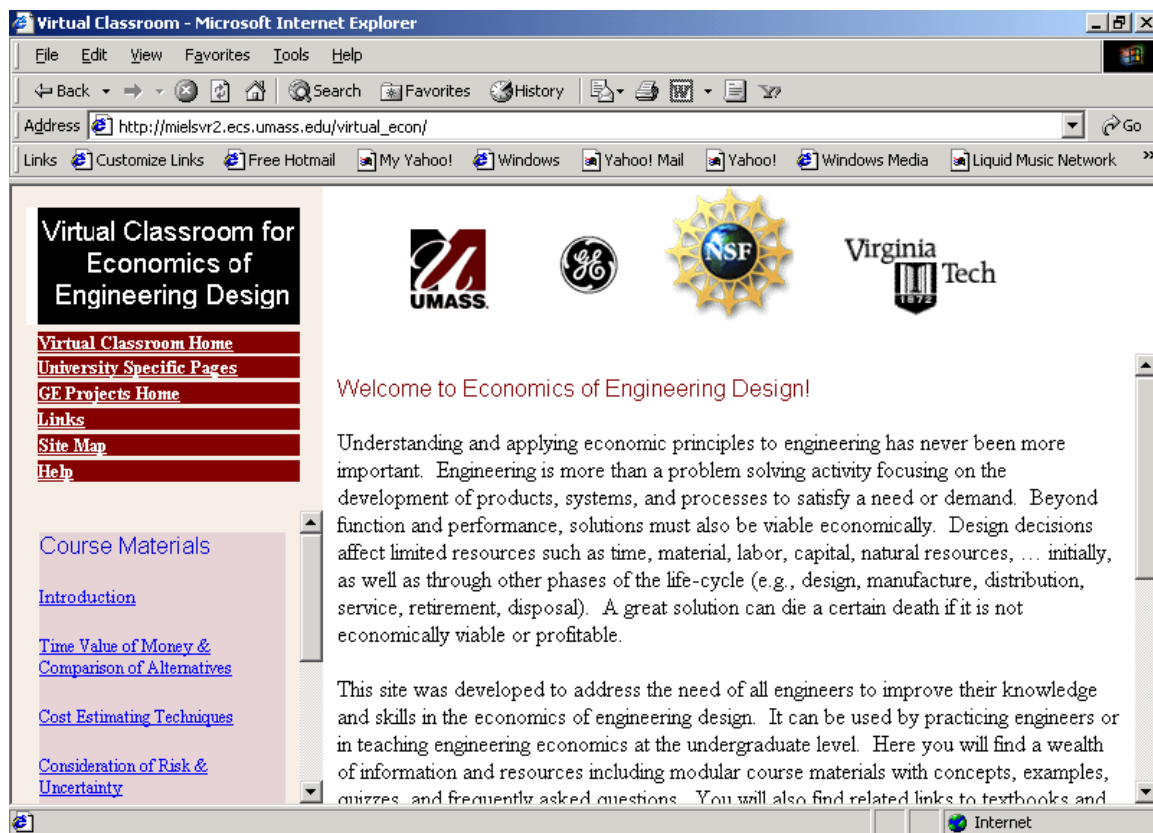

Figure 2. Virtual Classroom home page

This consistency helps users navigate the classroom effectively and gives an intuitive feeling about where items are located and the layout of the system. From the front page several different areas can be reached. These include University Specific Pages, the GE Projects page, a Site Map, Help pages, and the course materials. The links on the home page under course materials will take the user to a new page with similar construction.

All of the course materials pages were designed to have certain design elements in common with each other. The course modules are set up inside of a frame system. This was deemed highly usable because it gave a clear and consistent area for different sorts of work and provided an easy frame of reference for the viewer. On the left hand side of the course pages is a frame that remains constant throughout the use of the module. This layout is illustrated in Figure 3.
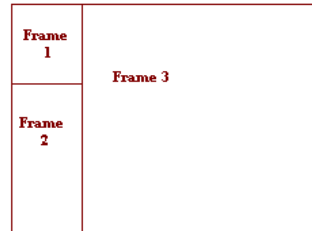

Figure 3. Course Module

Frame 1 is the same in all the course modules. It contains links to the other main areas of the virtual classroom. These links are to the Virtual Classroom Homepage, University Specific Pages, GE Projects Home page, Links, Site Map, and Help pages. Refer to Figure 4 below where The Time Value of Money and Comparing Alternative module is provided as an example of the standard format and common links.
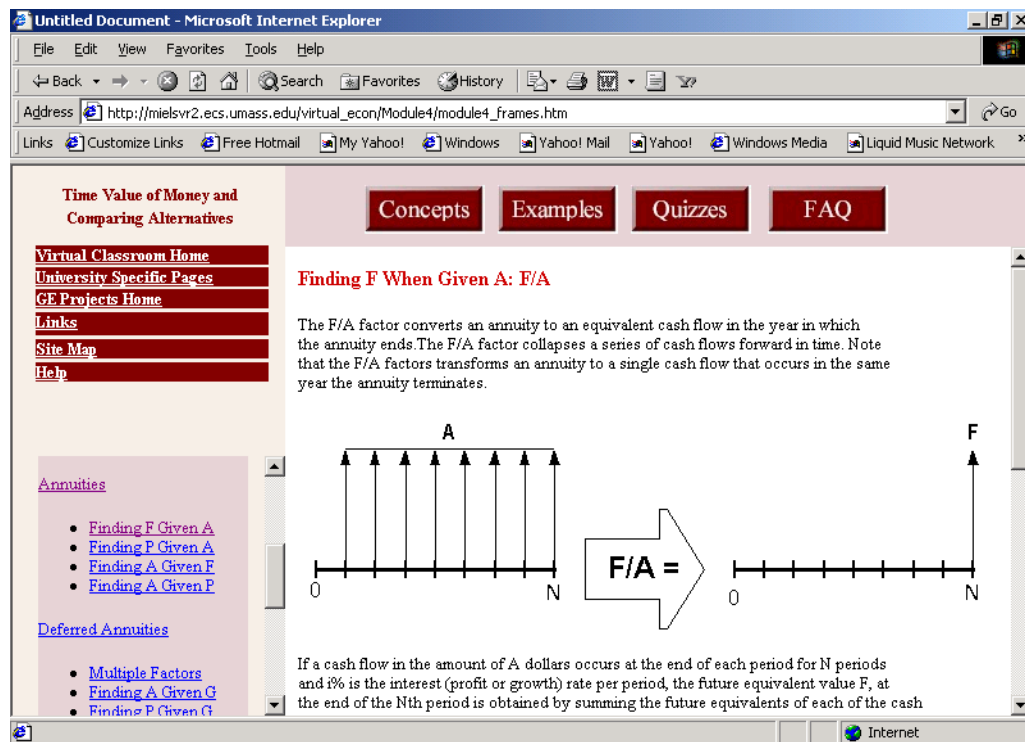

Figure 4. Example of format and common links.

Referring again to Figures 3 and 4, Frame 2 contains a listing of all the sub-topics. Clicking on any of these links will bring the corresponding material into Frame 3 for further exploration. When the list is long enough, this frame becomes scrollable with a sidebar down the right-hand side.

Frame 3 is the main frame for information display. This is where the introduction to the module, course lessons, examples, quizzes, frequently asked questions, and other pertinent information is displayed. It can either have an additional top-frame for browsal of more sub-topics within it or be frameless. In the case of the home page for the virtual classroom this top frame consists of links to the sponsors and collaborators involved in this project.

Within a course module of the virtual classroom this system remains constant. Frame 3 is subdivided into two lower-level frames. Refer to Figure 5 for the case when a sub-topic of the module is selected.
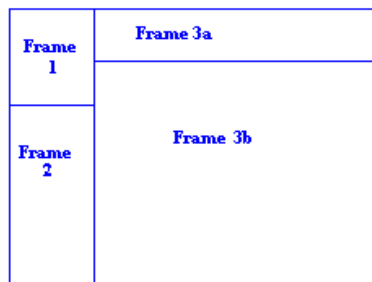

Figure 5. Sub-topics within Frame 3

Frame 3a stays constant throughout the use of each sub-topic. It has buttons that act as links within the sub-topic. These buttons include items such as "Concepts", "Examples", "Quizzes" and "FAQ" for Frequently Asked Questions. As the mouse is moved across the buttons, the buttons change color or highlight. Clicking on a button will bring up the corresponding material in Frame 3b. The material in Frame 3b is all the course lessons, quizzes, etc. This frame becomes scrollable when the content becomes too long to fit into the standard frame size.

The different sub-topics are clearly defined. The concept section is the actual material to be learned in the sub-topic. In conjunction with the other parts of the sub-topic is the lesson/supplementary material for that topic. The concept section is typically an overview of definitions, formulas and ideas. The examples section is designed to give more detail and show how the concepts are applied. The quizzes are set up in general as multiple-choice questions to test the knowledge learned from the modules. Once an answer is selected, text will appear to the side of the question stating whether or not this answer is correct. Refer to Figure 6 for an example on-line quiz.
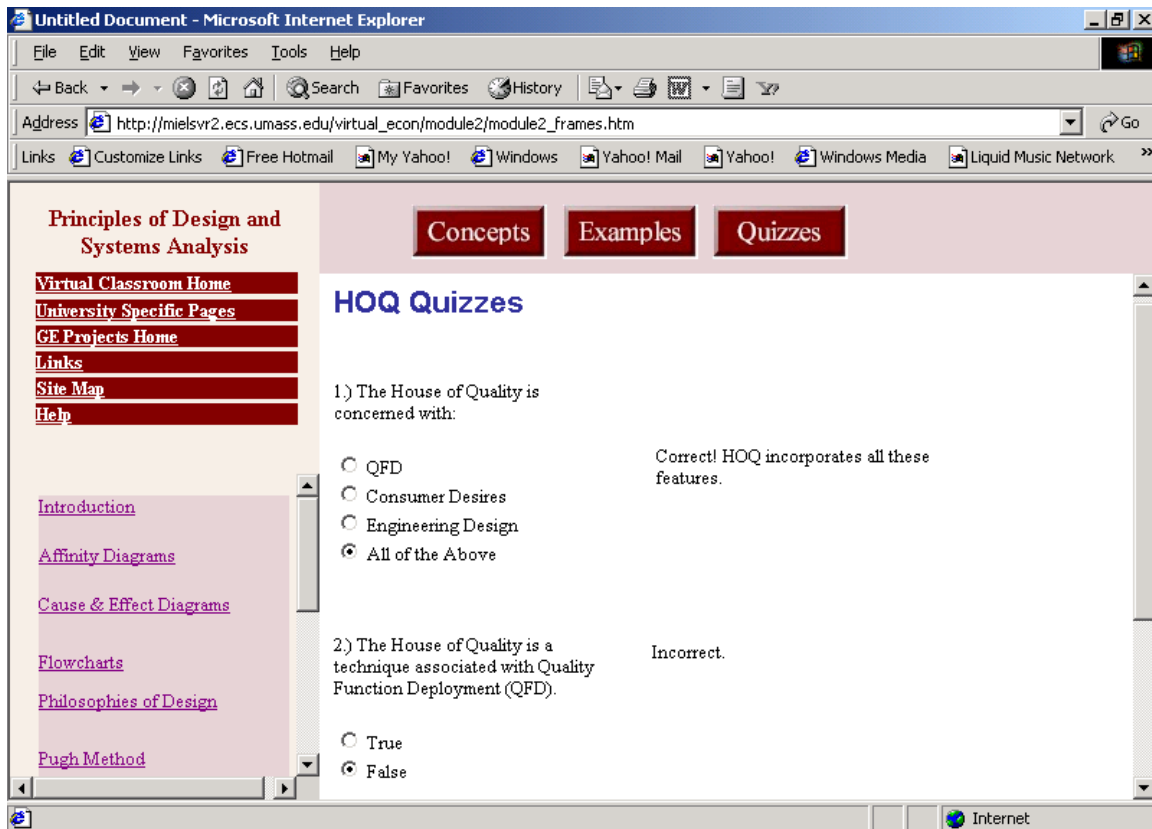
Figure 6. Example on-line quiz

Answers can be selected multiple times until the correct answer is found. There are quizzes for some sub-topics as well as an overall quiz for each course module. When not appropriate or when information has not yet been developed, buttons for certain areas are not in existence. The site module button within each module brings up the site index for that module; for the home page it brings up the site index for the entire project. Refer to Figure 7 for an example of a module site index.[9]
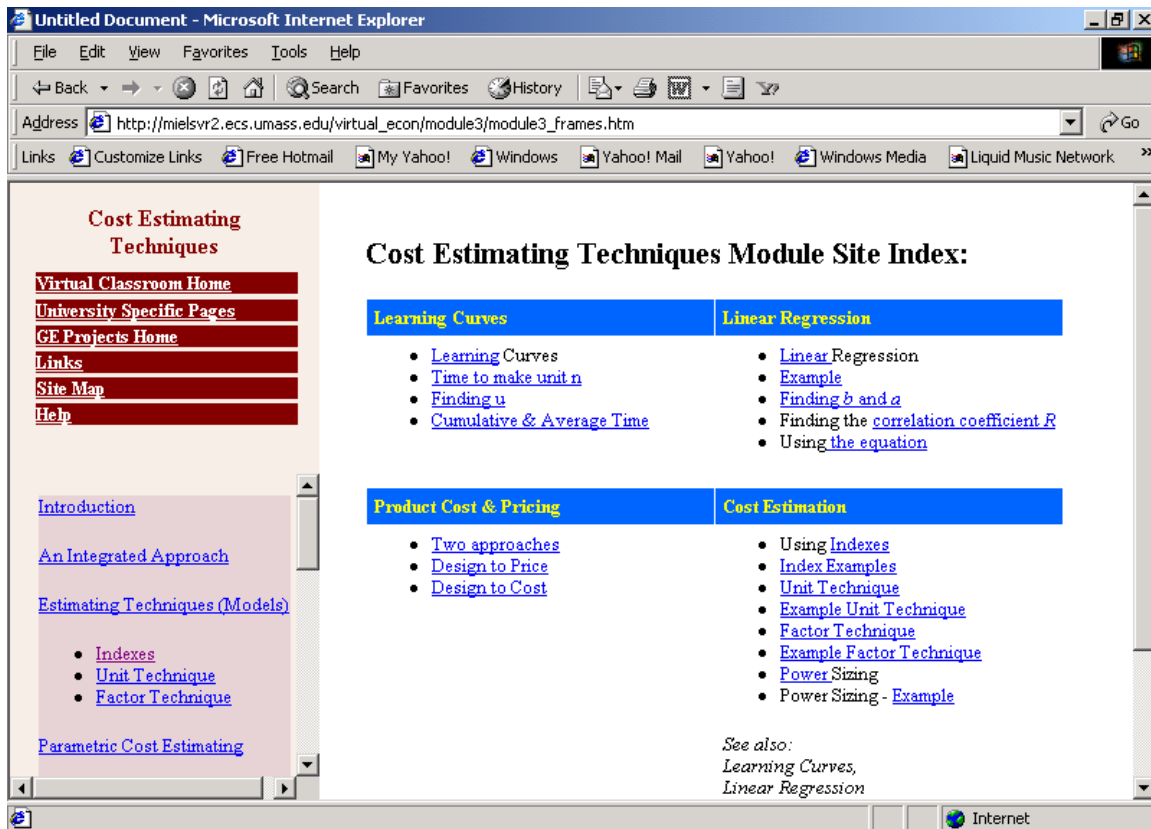
Figure 7. Example of a module site index

IV. Projects in Collaboration with Industry

One form of learning that is often underutilized is the use of industrial projects in collaboration with industry.[10] The final module in the virtual classroom, "Project in Collaboration with Industry", seeks to address this need. Refer to Figure 8 for the web page related to projects in collaboration with industry. This is a forum and tool for information about design problems presented to students by industry. Our current collaborators at General Electric Industrial Systems have provided four diverse problems for student projects. The projects seek to excite students with real world application of key concepts learned in class, self-directed learning that promotes student-industry collaboration, and a medium to foster collaborative learning. In addition, these projects and related experiences help students to better meet the needs of companies upon graduation by furthering their "real life" project experiences.[11]
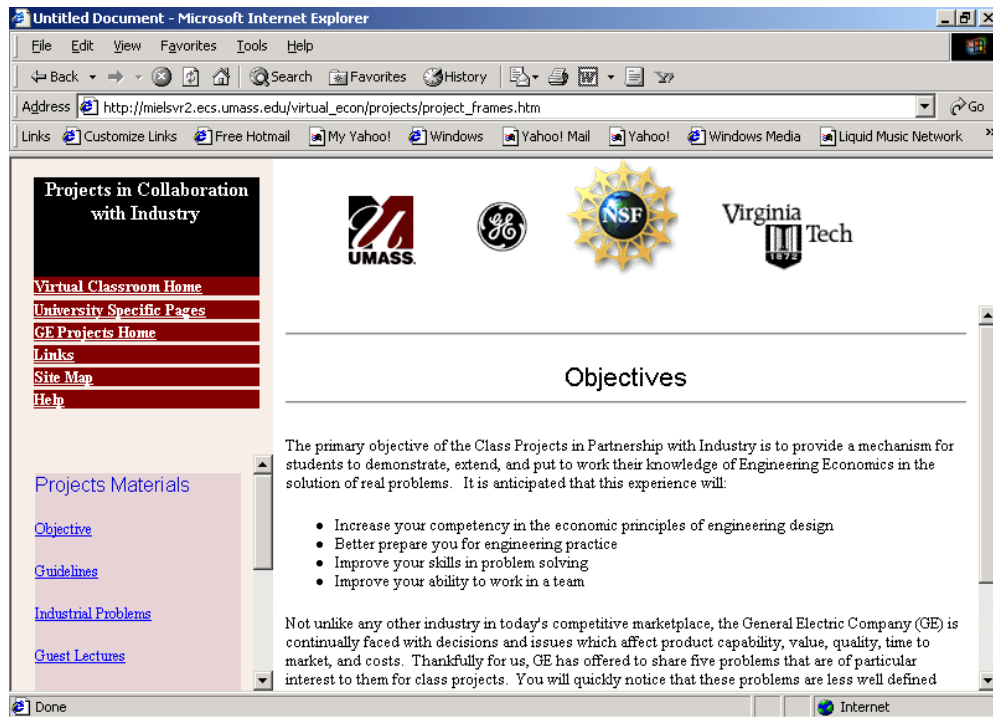
Figure 8. Projects in collaboration with industry

This module is slightly different from the other modules for several reasons. It takes into account that the teaching of economics of engineering design has shifted to a more discovery-based learning and problem solving style. In this case this is achieved through the investigation of design problems using economic principles of engineering design.[12]

The main goal of this module is the facilitation of industry-student collaboration through explanation and exploration of real life design problems. Students within the class work in teams on one of several problems. The design problems each had a different GE employee as a primary contact to answer questions, clarify concepts, and give support. The students within the class were given benchmarks for work and were required to work in teams to complete final reports upon their analysis. Classroom material, industry contacts, and subtopics in the module guided and helped students through the various steps of the project.

The module is composed of several sub-units and tools to help students fully understand the problems presented and comprehend how to use classroom concepts in real life situations. These sub-units include project management presentations, project statements, email contacts, and a message board.

Project management presentations were added to this unit in both streaming video and PowerPoint slides. The students in the class were required to go through a project management

presentation because it was deemed helpful in combating common team problem issues of leadership, responsibility allocation among team members, optimizing time, setting clear goals, and staying motivated.[13]

The project statement portion of this module presents several possible design problems. These problems were kept somewhat open-ended to allow students a degree of freedom in approaching them. There were no specific solutions to any problem given thus allowing students to apply classroom knowledge creatively. The solutions would depend upon the solution methodology employed in each case and garner different results and insights into the problem.

A message board was implemented in this portion of the project as an open forum for discussion about the industry-sponsored projects. Studies have shown that message boards significantly improve interaction and elevate the sense of community between class members in larger classes. This in turn improves the motivation levels, the quality of the work, and its retention.[14] Student-industry and student-student interaction was implemented through the use of this message board and email contacts.
The students were able to post questions for each design problem and an industry representative would receive an email relating to this action so the questions could be answered. Questions ranged from problem clarification to more specific topics.

The message board was implemented through DISCUS[15], a system based in Perl-CGI. It enables the use of passwords, and restrictive powers within its system as well as customization features. Refer to Figure 9 for a sample of the message board.
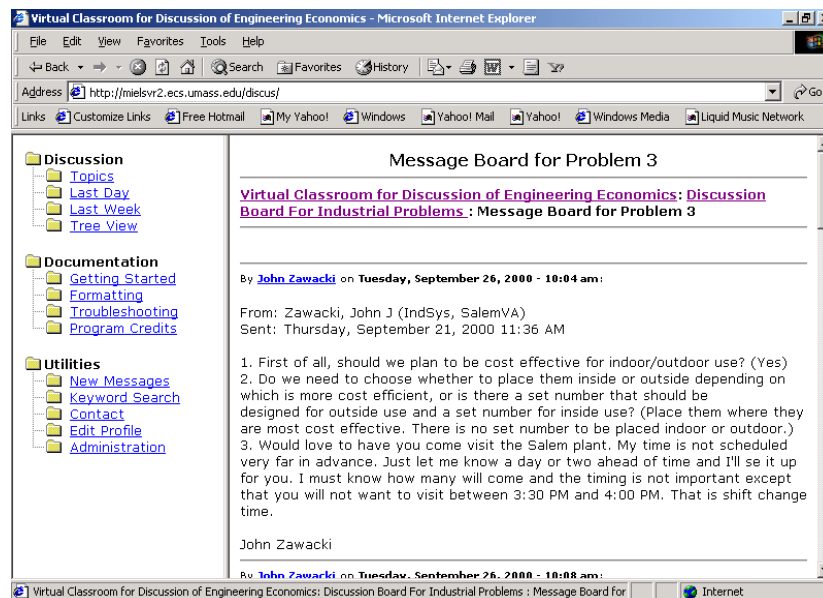

Figure 9. Message board for projects in collaboration with industry

There are several Internet based tools that were used for this project. At the end of the course, students were surveyed as to the usefulness/effectiveness of these tools (project statements, the message board, email contacts) used in conjunction with the industry-based projects. Based upon these surveys, the following results were recorded. There was 100% usage of the web pages, probably due to its required use in conjunction with the projects. The frequency of its use for the projects varied due in part to the dependency of the group on a team leader. The total frequency of students visiting between 2-4 times was 63% and the students visiting between 5-10 times had a 29% value. All students were asked to rank the projects site from "Not At All Useful" to "Very Useful." There were no "Not At All Useful" responses. Seventy five percent of those surveyed found the web site "Useful" and 25% found it "Very Useful."   Of all the tools analyzed the Message Board was found to be the least effective. Message board answers were often supplemented with email and there was some desire to minimize specific problem solution sharing on the boards so that different groups would develop unique solutions. This led to the students giving the message board a lower importance compared to the Internet based tools used. Industrial mentors' email was the most effective tool followed by student email.   This is probably a result of the students interacting with the industry representatives for most of their queries and guidance resulting in it being the most important tool.

V. Analysis of the virtual classroom and industrial problems

The results of analyses regarding student performance and perception for the industry sponsored projects and the virtual classroom are as follows. Students were divided into two groups for the purpose of this analysis. The experimental group consisted of those students who took the projects in collaboration with industry while the students who attended a conventional classroom acted as a control group. The analysis that was performed to determine the effectiveness of the classroom was based upon traditional techniques of assessment, consisting of written examinations and in-class surveys.[16,17]

The easiest way to adopt this methodology at Virginia Tech was to divide the two groups up according to sections. Thus the experimental group consisted of those students in the 8:00 am section while the control or conventional classroom was the students in the 10:00 am section. Both sections were taught by the same instructor and had the same tests and exams. The grading methodology differed only in the fact that 15% of the final grade was based on the project for the experimental group. However, for the purposes of analysis, identical weights were used for tests, homework, and the final exam. In this manner, the projects were given no weight in comparing the final scores of the two groups.

The analysis was based on the student grade point performance. All grades were adjusted to a 10-point scale for consistency. The difference in the student prior performance (control and experimental group) was evaluated by comparing grade point performance in senior and junior

level students. On a scale of 0-10, the difference of the grade point performance (experimental-control) was 0.03, obtained by 100 bootstrap samples[18] with replacement 40 times. Refer to Figure 10 for a graphical display of these results.
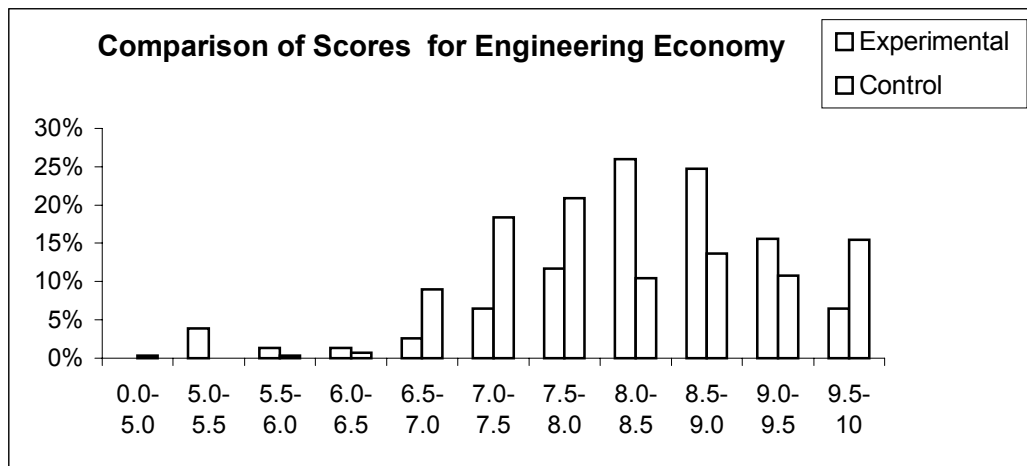

Figure 10. Comparison of scores for engineering economics

A two-tailed t-test was used to test for the difference between the final grades of the experimental section and the control section. The test statistics were normal with the Anderson Darling Normality test result p>0.05. The two-tailed t-test gave p=0 for the 8:00 AM experimental section mean being greater than the 10:00 am control section mean by at least 0.03 (previous score difference) at a significance level of 0.05. The test clearly indicates that the 8:00 am students out performed the 10:00 am class.

Analysis was also performed for those students involved in the class at UMass (See Figure 11). There was considerable difference in the average mean performance of the students who took the projects as compared to those students enrolled in the conventional classroom. The analysis of a two-tailed t-test gave the p value equal to zero for the hypothesis that the students who took projects performed better than the students who took the conventional class.

Variable	Mean	St Dev	SE Mean	Anderson Darling Normality
Exp. Group	8.563	0.413	0.041	0.330
Control Group	7.323	0.020	0.020	0.414

Figure 11. Bootstrap Statistics for UMass

The considerable difference in the above two means could be attributed to two primary factors. The students at UMass who were involved in the projects were honors students. Also as part of their work for the projects, they met with their professor once a week to discuss the projects in greater detail and received more personal attention than their conventional classroom counterparts.

Overall, student comments were positive about the experience of working on projects with industry collaborators. Most students stated that they liked working on real life problems.

VII. Conclusions and Future Work

The design of the collaborative module took several factors into account. Methods for exciting students and getting them involved with industry were examined. The best and clearest ways to convey information were examined. Presentations and problem statements were included to increase the knowledge base of the students and their excitement levels. Message boards and other contact information such as email were included to increase interactivity. Guest lectures were incorporated to allow students to hear and see presentations that otherwise would not have been available to them due to logistical concerns.

Using the bootstrap method at a significance level of 0.05, the grade point average of the students developing solutions to the projects in collaboration with industry (Experimental Group) was higher than those receiving only the traditional classroom style lecture (Control Group).[19] Further analysis is planned on the effectiveness of the entire virtual classroom, including the learning modules. At the time of this first analysis, these modules were not as fully developed. A second experiment has already taken place since the first analysis. The next set of results, which should be forthcoming in the very near future, will examine not only the effect of the industry collaboration, but more generally compare the use of technology in teaching the economics of engineering design. The experimental and control groups for the second round of analysis should distinguish clearly whether technology positively impacted the learning experience. Further, in the second experiment, the study at UMass was not limited to honors students, but included students of all capabilities.

This research has been a collaborative effort including Virginia Tech, the University of Massachusetts-Amherst, and the General Electric Company. As envisioned, the virtual classroom will remain an open resource on the web that can be used by any university in teaching a first course in engineering economics. In addition, it is anticipated that it will serve as a continuing resource that students can return to regularly throughout their education and serve as a resource for practicing professionals. Farther reaching, this research is an integral part of a longer-term and broader vision to build an undergraduate "National Technological University" (NTU) for selected core courses in the engineering curriculum. It is anticipated that through computer-based learning methods utilized at the undergraduate level, higher quality core engineering courses can be offered to more students in a very cost-effective manner.

Further expansion and development of the Virtual Classroom for Economics of Engineering Design is planned. These plans include the expansion of sub-topics, an increase in the number of quiz questions and areas covered. As mentioned previously, more detailed analysis of the effects of the virtual classroom should be available in the near future.

Acknowledgments

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Biographies

JANIS P. TERPENNY
Janis P. Terpenny is an Assistant Professor of Mechanical and Industrial Engineering at the University of Massachusetts, Amherst. Her research interests are at the intersection of information technology and engineering with a focus on engineering design methodology, education, and solutions for persons with disabilities. Dr. Terpenny has several years of industrial experience and continues to work actively with industry in joint research. She received a B.S. degree in Applied Mathematics from Virginia Commonwealth University and M.S. and Ph.D. degrees in Industrial and Systems Engineering from Virginia Polytechnic Institute and State University.

KIMBERLY SWARD
Kimberly Sward is currently a MS/PhD candidate in Industrial Engineering at the University of Massachusetts at Amherst. She received a B.S. in Biomedical Engineering from Rensselaer Polytechnic Institute in 1998. Her research interests include the incorporation of design methodology and real life problems and solutions, assistive technology, and economic representation.

WILLIAM G. SULLIVAN
William G. Sullivan is a professor of Industrial and Systems Engineering at Virginia Polytechnic Institute and State University. He is a two-time recipient of the Eugene L. Grant Award for the best paper in *The Engineering Economist*. His research interests include justification of advanced manufacturing technologies, the economic principles of engineering design, and activity-based costing applied to the design process. Dr. Sullivan serves as coeditor of the *International Journal of FAIM* and is a fellow in the Institute of Industrial Engineers. He obtained his Ph.D. in Industrial and Systems Engineering from the Georgia Institute of Technology.