Engineering Theory and Practice via a Web-Link

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Abstract

Maintaining ABET accredited engineering programs requires hands-on laboratory experiences in addition to course instruction and theory. This paper presents some essential points to consider, and some “traps” to avoid, as digital (Semester on Line and Independent Study--Distance Learning) courseware is developed with laboratory elements that require hands-on applications.

Valuable insights gained (and lessons learned) from a two-semester teaching and skills development experiment in distance learning are reported in this paper. The experiment included basic instruction in the fundamentals of engineering graphics, coordinate and geometric tolerance controls (GD&T), and CAD. The primary objectives of the experiment was to develop a philosophy which would help to (1) ascertain the effectiveness of using the Internet as an effective means of course delivery, and (2) satisfy student interaction requirements in hands-on laboratory practice, using third-generation CAD systems. The authors developed a digital course extension that accomplishes both tasks. An engineering graphics course, taught on the BYU campus in Provo, Utah, was simultaneously offered, via the Internet, to students located at Ricks College in Rexburg, Idaho. The course contained a demanding CAD skills development and practice component, which could only be satisfied through a web-link to the CAE/CAD laboratories at BYU. Students at Ricks were able to participate in the synchronous lectures relayed via video and audio Internet conferencing, and/or they could use the Internet to access the asynchronous lectures stored on the BYU Web-server. This teleconferencing approach worked very well for the presentation of theory, facts, examples, demonstrations, etc. The challenge (and at least *one* workable solution), reported in this paper, was to develop an effective technique for providing an *interactive* hands-on element for the laboratory exercises, and operator skills development and assessment.

I. Introduction

During the past year the educational benefits of on-line instruction have been debated in *The Chronicle of Higher Education*^(1,2,3,4,5,6). Various authors have argued the foundational principles underwriting the “virtual university” and whether or not, such an innovative development can meet the high standards of traditional colleges and universities¹. The question has also arisen regarding accreditation for such offerings³, and, if accredited, to what measure of quality⁴? The

positions taken by some of the authors makes it clear that there is some concern that accreditation granted to on-line institutions will bring the demise of higher education. Others hold to the belief that if the accreditation bar is maintained at a high level, there will be no measurable difference between the traditional and on-line courses or degrees. While this debate will likely persist for years to come, the simple truth is that on-line instruction is here to stay, and it will play an important role in life-long learning for current and future engineering students. How much of a role it will play in their degree program is yet to be determined.

Some support the notion that on-line instruction came into existence with the creation of the Internet. The truth is that two-way television educational and professional training broadcasts from many campuses have been ongoing for decades. In 1980 Dr. Jensen viewed an on-line MBA tele-broadcast from Stanford University to the Lockheed facility in Sunnyvale, California. The literature is full of case studies and examples where this tele-instruction has been successfully implemented and used throughout the world^(7,8,9,10,11). The Internet has made possible the ability to reach into an individual home with on-demand education and training.

The Internet has the potential to reach millions of students. It is imperative that the academic community develop and establish accreditation solutions to on-line instruction. Kessler et. al., and Bork and Britton found most of the web-courses they examined poorly designed and non-interactive⁽¹²⁻¹³⁾. Considering current on-line engineering curricula, the authors have likewise found the material incomplete and conspicuously lacking in hands-on laboratory elements. In the authors' opinion, it is inappropriate—if not irresponsible—for any institution to offer on-line instruction in a format that is unprofessional in organization, presentation, and delivery. Equally important, it must be responsive to *interactive* exchanges to underscore the learning process.

Maintaining ABET accredited engineering programs requires a combination of both structured and unstructured hands-on laboratory experiences, and rigorous theoretically accurate instruction, all of which leads to definable, measurable engineering outcomes in students' abilities to analyze and solve engineering problems. This paper presents some essential points to consider, and some "pitfalls" to avoid, as digital (Semester-on-Line and Independent Study—Distance Learning) engineering courseware is developed and made available to "on line" students—on campus or at remote locations.

II. Background

Engineering education must undergo extensive philosophical and practical reformation if engineering students of the twenty-first century are to possess the knowledge base, technical strengths, and practical and interpersonal skills that will be required to undergrid America's leadership position in a world economy. Much of what will occupy the time of "next generation" design engineers will be based on a global virtual engineering space. Leading experts have called for the immediate reform of engineering curricula in light of the technology and information explosion that has occurred during the last decade^(14,15,16,17). Distance learning, if done correctly, can serve as the catalyst in the evolving process of engineering education reform.

Terms and definitions are important aspects of this paper. "Distance learning", for example, has inherited various interpretations among educators and researchers. Distance Learning or

Distance Education first appeared in print in 1892, and was popularized by the definition provided by Garrison and Shale 1987 “—any formal approach to learning in which a majority of the instruction occurs while educator and learner are at a distance from one another”¹⁸. Since then the interpretation has been extended to mean anything from the printed and written correspondence by mail programs, referred to as independent study or external studies, to their more modern counterparts i.e., semester-on-line, or virtual classroom. To avoid misunderstanding, and to add clarity of intent, the authors have embraced the following definitions: Distance Learning (DL) is *any on-demand Web-based courseware that requires the learner to study a subject, take tests, submit homework, send email, and in general, correspond with course instructors or teaching assistants who are in possession of learning support materials*. Some educators have referred to this definition as “Interactive Distance Learning” because it requires the learner to take an active role in the learning process. The authors, however, have a more dynamic definition of *Interactive Distance Learning (IDL)*: —*any live, Web-based sharing of courseware and/or hardware or software resources, point-to-point or multi-point conferencing, text-based chat rooms, team collaboration, etc, which allows students at remote or distant locations to link, via the Web, to campus-based laboratory equipment for on-line instruction and student manipulative exercises*.

Telecourses or Telebroadcasts are *any television-based or Internet streaming video broadcast that provides educational curricula and programming to connected sites*. The Public Broadcast Service (PBS) is certainly a key player in providing such educational service. They currently provide over eighty telecourses and five teleWEBcourses covering a variety of subjects¹⁹. Many universities throughout the world provide similar kinds of programming to remote campuses or industrial sites. In a survey of some major universities it was found that little if any of their telecourses focused on engineering. Hodes expresses his opinion that the lack of scientific topics within distance learning offerings is due to the hands-on laboratory requirements²⁰. He also suggests that as the level of education within the engineering disciplines increases, so also does the need for more interaction between student and instructor, as well as access to facilities and equipment.

BYU currently has more than 40,000 students enrolled in DL courses, available by mail, the Internet, and CD-ROM. Bateman, president of Brigham Young University, predicts that the student enrollment in DL courses will increase many times as more students become aware of current course offerings, and as the total course offerings are expanded²¹. Hwang suggests that the ultimate goal of DL systems is to provide the remote participant *most* of the capabilities and similar experience to those gained by in-class participants²². According to Whalen, the results of many DL case studies have concluded there is no significant difference in educational outcomes, when the work of resident students and students at remote locations were compared²³. It is the view of the authors, that the on-campus and remote students experience must be *equivalent in learning and practice* to be the same course, leading to the same degree, and having the same accreditation. As BYU expands its distance course offerings in engineering we concur with Simonson, who insists that distance learners, in any course, must have the same opportunities and resources that are made available to the on-campus students²⁴.

Through the uses of software packages like NetMeeting, pcANYWHERE, CU-SeeMe, etc., students in remote locations can link up with on-campus students, staff and faculty from their

homes, libraries, or work places. These packages allow individuals to access, through the Internet, video conferencing help sessions, lab sessions or even live course lectures from anywhere in the world. It is also possible, using these packages, to share or access any application that resides on Windows/NT servers during these sessions or course lectures. Bassett demonstrated the sharing of Pro/E, a third generation CAD system, over the Internet using NetMeeting²⁵. The demonstration was an attempt to reduce travel time between researchers at Purdue and Cummins Engine while working on a centerless grinding research project. Casucci has also used NetMeeting to share results from a laser micrometer and from a Tallyrond surface analyzer with engineers located at a remote site²⁶. Using the NetMeeting connection, engineers can discuss, modify, edit, and re-execute detail definitions and measurements; all without the need to mail samples to the remote site or requiring the engineers to travel to the site where the inspection tools reside. During the summer of 1997, Dr. Jensen was successful in using NetMeeting to control a remote 3-axis milling machine. He has since used NetMeeting over the Internet to remotely control or share a 2-axis lathe, a surface analyzer, tensile tester, coordinate measuring machine, plus a number of high-end CAD/CAM packages.

Engineers, located off-site have used other Internet tools to gain access to resources not locally available. Bischel developed a telemanufacturing capability for doing the engineering and rapid prototyping of components over the Internet²⁷. Loss has explored distributed collaborative design, via a web browser plug-in, that provided access to the Alpha-1 CAD system²⁸, and Spath has developed a virtual reality (VR) web-based system for collaborative design, programming, simulation, and testing of programmable logic controllers²⁹. This system is easily shared over the Internet allowing students or engineers at remote sites to create VR scenarios that emulate work cells, individual machine tools, or other manufacturing systems. In a similar manner Shivananda has developed a web sharable VR engine for material processing within extrusion die design³⁰. Not many remote students or engineers have access to a Hexapod milling machine. However, through the efforts of Falco, NIST has developed a VR tool for programming and simulating the Ingersoll Octahedral Hexapod, and Mori has successfully developed a system for remote monitoring and diagnostics of machine tools³¹⁻³². Several machine tool builders (i.e., MAZAK, TREE, MAKINO, etc.) and control systems manufacturers (FANUC, Siemens, Mitsubishi, Vickers, etc.) are currently using products like pcANYWHERE to conduct remote monitoring and diagnostics of installed machine tools. This is also being offered to the users of these machine tool systems as an Intranet monitoring and diagnostics tool.

III. Collaborative Enabling Efforts

Starting in the summer of 1997 Dr. Jensen began experimenting with interactive third-generation CAD tools over the Internet. While participating in a NSF sponsored Collaborative Manufacturing Initiative at Purdue University, he was able to remotely share Pro/E. Through Internet connections, students at the remote sites were able to take control of the Pro/E software that resided on an NT workstation at Purdue. Through the use of NetMeeting, the students simply clicked the mouse to take control of the Pro/E software, and were able to build complex three-dimensional solid models and run analysis or manufacturing applications against them. Through this experience, Dr. Jensen was convinced that a closer look at IDL of third-generation CAD was warranted.

During the fall semester, 1997, Dr. Jensen proceeded to test the remote sharing and control of Pro/E via the Internet; first between two on campus engineering buildings (see Figure 1), then to a conference center 45 miles away from the university, at Park City, Utah (see Figure 2), and finally to his home in Provo, Utah. These connections were between a T1 line at the university and a laptop 33K-baud modem. During the tests the remote individual was able to access the NT-servers at BYU, where a student shared his Pro/E license. The manipulation and control of Pro/E was slow, but participants were able to create solid models, revolve and render them, and evaluate their dimensional characteristics. These fetes were accomplished while the individual at the remote location was being coached by a person at BYU. The coaching was done through audio commands and discussions carried by NetMeeting. Video links were also used at the beginning and end of these tests as a greeting and sign-off process. The video images, captured at each site by “QuickCam” cameras, were extremely slow and low quality. This was due to sending a large amount of information (Pro/E, two-way audio and video) down a small, slow pipe.

Figure 1: Sharing Pro/E building to building – on campus

Figure 2: Sharing Pro/E to remote conference center – Park City, UT

Armed with these experiences Jensen and Raisor next attempted to link a classroom at Ricks College, in Rexberg, Idaho, to a NT-server at BYU. This was done to determine if faster connections to the Internet improved the remote sharing and control of Pro/E. Using T1 and T3 connections to the Internet, Ricks College was able to link back to BYU and take control of Pro/E with the simple click of the mouse. During this connection both locations broadcasted audio and video while sharing the modeling and creation of solid impeller wheel. Figures 3 and 4 show some of the results of this exercise.

Figure 3: Internet links between BYU and Ricks

Figure 4: Internet sharing of Pro/E impeller model

This connection was so successful that a group of faculty and administrators at Ricks College, and the authors, decided to propose a live interactive engineering graphics course that would originate at BYU but be offered via the Internet to students at Ricks College (see the section on synchronous remote engineering graphics).

While visiting with Dr. Noel Leon Rovira at the Institute of Higher Learning at Monterrey in Mexico, a connection to BYU was established and Dr. Jensen was able to begin teaching a CAD engineering applications course at BYU. NetMeeting was used to broadcast the audio and video from Monterrey. The connection also allowed access the Pro/E software that resided on a NT-server at BYU. During the class he was able to discuss, demonstrate, and evaluate proper rendering procedures for complex solid models, see Figure 6. With a simple click of the mouse he was able to take control of the Pro/E CAD software at BYU, from Monterrey, Mexico, and the students at BYU were able to interact with him, see him, hear the lecture material, and participate in the exercise.

Figure 5: Internet links between BYU and Monterrey

Figure 6: Internet sharing of Pro/E impeller model

Later, Dr. Jensen executed an overseas Pro/E link to test the viability of sharing high-end CAD systems over the Internet—via satellite, see Figure 7. Working with Dr. Mitsuishi at the University of Tokyo, and using NetMeeting on a networked PC, the call was successfully

received and all aspects of the NetMeeting collaboration and sharing of Pro/E were successfully accomplished, see Figure 8.

Figure 7: Internet links between BYU and Tokyo

Figure 8: Internet sharing of Pro/E impeller model

One year after this visit Dr. Jensen return to Japan where he tested other NetMeeting links;

- 56K-baud modem to a T1 BYU connection
- 56K-baud modem to a 56K-baud connection

It was discovered that while the 56K to T1 connection was usable for interactive CAD, it was unacceptable if video was shared while attempting to do both audio broadcasting and CAD manipulation. It was also found that the 56K to 56K connection was good for both audio and video, but any type of data or application sharing beyond Microsoft Office products, was not possible.

One month after the second Japan trip the testing of a 56K-baud to T1 connection between Sweden and BYU and 56K to 56K connection was also conducted. Again, the 56K to T1 connection was found to be usable to access CAD software at BYU if live video was not used. The 56K to 56K connection was also found to be good for both audio and video but any type of data or application sharing beyond Microsoft Office products, was not successful.

IV. Synchronous Remote Engineering Graphics

Two educational frontiers, related to the remote engineering graphics offerings, have been underway for some time at BYU: (1) Twenty-four years of teaching interactive computer graphics, and (2) Experimentation into interactive remote CAD sharing. The following information provides an overview of faculty preparation and expertise in these areas.

Graphics is the international language of engineering. Interactive computer graphics related to design, modeling, simulation, manufacturing, and assembly, are significant tools in the engineering enterprise. The principles of interactive computer graphics in design, and the level of CAM and CAE literacy and skills possessed by graduating students in engineering, are subjects of concern shared by industries seeking qualified entry-level engineers. The emergence and convergence of revised national and world standards (ASME/ANSI/ISO), has heightened

uncertainties regarding engineering students' preparation to read, write, correctly interpret, —and process, governing standards in a global industrial environment.

Motivated by these expectations and the challenged by additional concerns about minimizing time to complete an undergraduate degree, Professor Raisor, developed an integrated graphics course. The course combines the fundamentals of graphics principles and descriptive geometry, dimensioning and tolerancing standards (ASME Y14.5M-1994), interactive computer graphics, and the fundamentals of geometric modeling (CAD). Significant developments in organization, preparation, and delivery were required. Time-related problems demanded innovative and creative teaching/learning solutions that affected both instructor and students, and which has led to greater reliance on students to learn —independent of instructor involvement. To accommodate the combined requirements, various instructional philosophies and student mentoring techniques have been considered. These include rapid sketching techniques, team laboratory exercises, peer mentoring, student team collaboration, coaching by teaching assistants, and comprehensive modular multimedia presentations.

As indicated earlier, in the fall of 1998 a classroom at BYU was linked via the Internet to a classroom at Ricks College in Rexburg, Idaho see Figure 9. Using a 300MHz PC at both locations connected to overhead projection units and classroom sound systems, a NetMeeting call was initiated at BYU calling the remote computer's IP address. This setup allowed Professor Raisor's PowerPoint lectures to be seen and heard not only by the 169 students in the BYU lecture hall but to also be broadcast to 30 students at the Ricks location. This fifty-minute connection was made three times a week for fifteen weeks.

While the PowerPoint lectures focus on the learning and application of graphic principles and national standards, another component of the class is skills acquisition on third-generation CAD systems.

Figure 9: BYU classroom with live Internet link to Ricks

Students, both local and remote, were given accounts on the BYU fileserver that manages the high-end CAD systems. Students were expected to complete nineteen laboratory exercises (10 tutored lessons, and 9 production drawings —including final assembly drawings), using the CAD system to model and define each mechanical component or assembly. Prior to assigning the lab projects, a live lab session was scheduled and conducted similar to the lecture periods. The only difference being that instead of PowerPoint slides being displayed and relayed to the large overhead screen, Pro/E was loaded and shared over the Internet. The students received, prior to the demonstration, a written outline of the project and procedures that the lab instructor would demonstrate during the fifty-minute period. Following the laboratory demonstration and exercise,

The BYU students went to the lab and completed the project, whereupon they were to link up with a Ricks student and mentor them in the modeling exercise, see Figure10.

The prevailing thought, in the early stages of the experiment, was that the BYU mentors and coaches would learn the Pro/E system better than the BYU control group, and that the experimental group, located at Ricks College, would likely show the least growth in skills development. Mentoring and coaching were activities that were considered critical to the distance learning experience. Matching of student schedules and time coordination among the team partnerships, assigned between BYU students and their Ricks counterpart, became a serious problem. That difficulty, coupled with poor initial audio connections during lectures and lab demonstrations, prompted professor Raisor to make some organizational changes and some slight hardware and software modifications before the beginning of winter semester 1999.

Figure 10: BYU student mentoring a Ricks student

As Findley discovered, it is imperative that there is a curriculum-driven offering, not a technology-driven offering³³. To correct the audio problems, a standard phone line was installed at each site to carry the two-way audio. This freed up more bandwidth and allowed the video of Professor Raisor to be broadcast along with the PowerPoint data presentations. We discovered, as Findley did, that two-way audio and video interaction enhanced the learning experience. It also made the Ricks students feel more a part of the class.

The organizational change implemented during the second semester, was to allow the Ricks students direct access to the Pro/E licenses without relying on a BYU student to share the CAD package. While this required an on-site CAD TA at Ricks, it did allow them to access and use the system based only on their schedules without coordinating with a BYU coach or mentor.

V. Findings

The following results were reported, based upon a two-semester educational experiment involving the instruction of a web-based interactive engineering graphics course, which included a weekly hands-on interactive laboratory component, a student opinion survey, and test results³⁴:

- Ninety percent of the students at Ricks College rated the *overall experience* as very favorable.
- Sixty-three percent of participating Ricks students rated the class *interaction* (two-way audio/video) as very favorable.
- Students at Ricks were evenly divided in their opinions regarding the importance of *viewing the live video* of the instructor during lectures and labs.

- In spite of the scheduling difficulties, a majority of students (65%) at Ricks rated the *collaboration* experience (working with a team of students at BYU) as very favorable.
- A favorable (70% +) rating was given to the in-class PowerPoint instruction methods.
- When considering the usefulness of the asynchronous PowerPoint resource materials, 78% of the Ricks students rated them *very useful to hard to do without*.
- Usefulness of the comprehensive class Web Site, 70 % of the students at the remote site rated it *very useful to hard to do without*.

Other data suggested that Ricks College students learned operator skills on a par with students at BYU. BYU students scored in the 6-7 range on a Pro/E skills rating test, while the students at Ricks scored an average of 5.3. In all other tested areas, however, the students at Ricks either matched or exceeded the BYU scores. The data also indicated that coaching by BYU students was not as effective as was initially surmised. A graph depicting the findings is shown below.

Figure 11: Skills comparison between BYU and Ricks students

VI. Asynchronous Remote Engineering Graphics

In an effort to correct the problems and improve the results from the first two semesters of the synchronous remote engineering graphics class, the authors are currently developing a new *asynchronous* approach. It is simple in concept, but maintains the interactive skills development laboratory component in the class. When complete, the lecture portion, which includes the theory, principles and standards of engineering graphics, will be delivered asynchronously via the Web, to students anywhere in the world. Students, who register for the class, will receive a password, giving them access to the class's Web site. In addition, they will receive a diskette, which will include a terminal server program, allowing them to access CAD software using one of the licenses assigned to BYU.

The current plan is to provide twenty-four hour CAD TA support so that any remotely located, resident (Semester-on-Line), or local/off-campus student can link to the BYU CAD lab, using

NetMeeting or some other Web conferencing application, and receive assistance while connected through a terminal server. Based on the success of this first class, other advanced CAD-linked courses will also be ported to an asynchronous offering. It is intention of the authors to develop a series of classes, leading to certification in CAD, and which will distinguish various levels of operator skills and engineering applications. Given this option, IDL students will not only get credit toward graduation, but will also have a skill that can help support them as they advance toward a degree. This concept has special relevance when the students are citizens of developing countries where industrial needs exist, but skilled practitioners are difficult to locate.

Figure 12: Example of asynchronous course material - Line Drawings

Figure 13: Example of asynchronous course material - Photograph and Dynamic Animation

Figure 14: Example of asynchronous course material - Video Clip beginning frame

Figure 15: Example of asynchronous course material - center - Park City, UT

The present course offering consists of eleven unit presentation or lessons. Each presentation is underwritten with specific behavioral objectives, and topics are carefully structured to provide an orchestrated approach to meet those objectives. Multiple visual images, including line drawings, photographs, dynamic animations and video clips are used to accentuate and give meaning to the learning process, see Figures 12-15. In addition, problem exercises requiring graphics solutions are presented, followed by documented step-by-step solution sets to assist students in understanding the basic principles involved in imaging and defining part geometry as illustrated in figures 16-17.

Solve For True Size and True Angle

Given: Top and front orthographic views of Surfaces A, B, and C.

Required: Construct auxiliary views to display the true angle between surfaces A and B, and surfaces B and C (two separate problems). Project views to show the true size and shape of surfaces A, B, and C (three separate problems).

Begin by verifying the projection and adding a reference plane through the lowest point in the top view.

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Figure 16: Example of asynchronous step-by-step course material – Problem Definition

Solve For True Size and True Angle

[Solution Slides] Next construction views.

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Solve For True Size and True Angle

[Solution Slides] This view displays the true angle.

Return to the Previous Slide

Solve For True Size and True Angle

[Solution Slides] This view displays the true angle.

Return to the Previous Slide

Solve For True Size and True Angle

[Solution Slides] Joining the points together in this view displays the true angle between planes B and C. Remember, *true angle is always displayed between edge views of intersecting planes*. Therefore, we can now project true size and shape views from the newly produced edge views.

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Figure 17: Example of asynchronous step-by-step course material – Problem Solution

The conceptual and progressive elements that are specific to each study unit are available to students through hyperlinks in its table of contents. Also, a comprehensive glossary (covering all course materials), highlighting basic principles, terminology, and technical concept definitions—even examples of working relationships—is available from any location in the course presentation, via integrated hyperlinks. These linkages have been established to emphasize continuity, and to demonstrate the need to accurately model, define and control geometry in the processes of design, manufacturing, and verification.

At appropriate intervals in each study unit, student understanding of relevant concepts is self-evaluated. Self-administered quizzes and decision charts regarding correct applications of geometry construction, coordinate dimensioning and tolerancing, and geometric tolerancing standards, are presented and corrected on-line, see Figures 18 and 19.

Figure 18: Example of asynchronous course material - Decision Chart

Figure 19: Example of asynchronous course material - Application Summary

This is done to help students understand the relationships between modeling, defining and controlling component geometry. Manufacturing processes—including process tooling and inspection techniques—are also introduced and illustrated in an effort to underscore the significance of accurate communications in the work place, see Figure 20.

Figure 20: Example of asynchronous course material – Process Tooling

At the conclusion of each lesson, a comprehensive unit examination is administered. Examinations are taken when students are confident they are ready. Prior to the test experience, they may access and review the materials in the lesson as frequently as they think necessary. Once the test has been accessed, however, resource lesson materials, other than personal notes, are unavailable to the student until the test has been completed, and the results submitted. When students indicate that they have finalized their answers, the tests are corrected on-line, with recommended topic and resource review for incorrect responses, see Figures 21 and 22. Test results are also relayed, via the Internet, to the university for accounting purposes.

Figure 21: Example of asynchronous course material - Unit Test, problems 7 and 8

Figure 22: Example of asynchronous course material - Unit Test, problems 23 and 24

A critical element of the unit and final examinations is the hands-on creation, editing, and defining of graphic models on the CAD system, shared from BYU. Model creation and manipulation, as well as dimensional definition, and control using appropriate coordinate and geometric tolerances are significant elements in these examinations.

The authors have become convinced of the significance of dynamic illustrations in the process of learning. Professor Raisor has prepared over 4,000 illustrations that are used in the presentation of materials in the course. Several forms of illustrations are used as previously noted, but most popular among students are graphic animations and streaming video clips, see Figures 23-26.

Figure 23: Example of asynchronous course material - Streaming Video, start frame

Figure 24: Example of asynchronous course material – Streaming Video, intermediate frame

Figure 25: Example of asynchronous course material - Streaming Video, intermediate frame

Figure 26: Example of asynchronous course material - Streaming Video, end frame

As explained earlier, remote students will learn the theory and application of graphic principles via the asynchronous Web-course, however, the development of modeling skills and the applications of design theory related to CAD modeling is provided through terminal server client. Students at remote sites will use the Internet to access computer resources at BYU and check out licenses for Pro/E, CATIA, UG, or Ideas, see Figures 27 and 28. These systems allow students to construct objects using either surface or solid modeling techniques. Students are assigned laboratory exercises that reinforce the engineering graphics principles that are covered in the asynchronous course, which integrate the strengths of both the asynchronous material and interactive practice or use of engineering hardware and software recourses.

Figure 27: Example of terminal serving – Pro/E

Figure 28: Example of terminal serving – UG

VII. Conclusions

While the Internet is capable of delivering live lectures to remote sites, it is not presently capable of doing it at the same quality level as telecourses. As Internet bandwidth and speed improves, and as audio and video compression algorithms get increasingly better, the Web will become a more viable tool for the delivery of synchronous course offerings. Even with the anticipated improvements, however, the authors are not convinced that synchronous lectures will truly succeed, simply because when it is 8 AM at the broadcast site, it is either an earlier (or much earlier) or later (or much later) time in all other time zones. Scheduling becomes the biggest problem with live remote lectures, not to mention the need for expensive multi-point conferencing units to split the broadcast signal or combine the remote inputs.

It is also clear that using class peers to coach remote students is not the most efficient use of either the coach's or the student's time. Having pre-trained teaching assistants who can readily assess the problem and direct a solution, is what the remote and local students need most. This is due in large part to the complexity of the CAD systems and the multiple approaches that can be employed to arrive at a viable solution.

In spite of some general difficulties associated with the acceptance of web-based distance learning philosophies and practicalities, this study has demonstrated the feasibility of sharing laboratory software and hardware, over the Internet, with individual students or groups of students, who are located at remote sites. There were also significant benefits that accrued to the web-based courseware, including an effective and informative comprehensive class web site.

Bibliography

1. F. Olsen, "'Virtual' Institutions Challenge Accreditors to Devise New Ways of Measuring Quality." *The Chronicle of High Education*, (Aug. 1999).
2. K. McCollum, "Colleges Urged to Use Technology to Promote 'Lifelong Learning.'" *The Chronicle of Higher Education*, (Sept. 1999).
3. S. Carr, J.R. Young, "As Distance-Learning Boom Spreads, Colleges Help Set Up Virtual High Schools." *The Chronicle of Higher Education*, (Oct. 1999).
4. D. Carnevale, "Distance Education Can Bolster the Bottom Line, a Professor Argues." *The Chronicle of Higher Education*, (Oct. 1999).
5. J. Perley, D.M. Tanguay, "Accrediting On-Line Institutions Diminishes Higher Education." *The Chronicle of Higher Education*, (Oct. 1999).
6. S. Crow, "Virtual Universities Can Meet High Standards." *The Chronicle of Higher Education*, (Oct. 1999).
7. M. Thorpe, *Evaluating Open and Distance Learning*, 2nd Edition. Longman Group: UK Limited (1993). 17-62.
8. O. Peters, *Learning and Teaching in Distance Education*. Kogan Page: UK (1998). 8-17.
9. L. Moran, "Flexible Learning as University Policy," in S.C. Brown (Ed.), *Open and Distance Learning: Case Studies from Industry and Education*, Kogan Page: UK (1997). 171-182.
10. D. R. Garrison, "Quality and Access in Distance Education: Theoretical Considerations," in D. Keegan (Ed.), *Theoretical Principles of Distance Education*, Rutledge: NY (1993). 9-21.
11. B. Vertecchi, "Structural Analysis of Distance Education," in D. Keegan (Ed.), *Theoretical Principles of Distance Education*, Rutledge: NY (1993). 152-61.
12. G.C. Kessler, K. Rosenblad, S.D. Shepard, "The Web Can Be Suitable for Learning," *Computer*, 32:2 (Feb. 1999). 114-15.

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13. A. Bork, D.R. Britton, Jr., "The Web is Not Yet Suitable for Learning," *Computer*, 31:6 (1998). 115-16.
 14. "Engineering Education Issues: Report on Survey of Opinions by Engineering Deans and Employers of Engineering Graduates on First Professional Degree," *NSPE Professional Engineers in Education Sustaining University Program*. NSPE Publication 3059, National Society of Professional Engineers (1992).
 15. "Engineering Education for a Changing World," *Report of a Joint Project of the ASEE Engineering Deans Council and Corporate Roundtable*. American Society for Engineering Education (1994).
 16. "Shaping the Future: new Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology," in *Report of the Review of Undergraduate Education by the Advisory Committee to the NSF Directorate for Education and Human Resources*. NSF 96-139. National Science Foundation (1996).
 17. G.M. Rogers, J.K. Sando, "Stepping Ahead: An Assessment Plan Development Guide," *Report of an NSF-Supported Workshop on Outcomes Assessment*. Terre Haute, IN: Rose-Hulman Institute of Technology (1996).
 18. J. R. Verduin, Jr., T. A. Clark, *Distance Education*. Jossey-Bass, CA (1991). 8.
 19. "Fall 1999 Telecourse Blockfeed Schedule." Public Broadcasting Service (1999).
 20. C.L. Hodes, "Developing a Rationale for Technology Integration." *Journal of Educational Technology Systems*, 26:3 (1997-98). 225-34.
 21. M. J. Bateman, "Brigham Young University in the New Millennium." *BYU Annual University Conference 24 August 1998*. URL: <http://advance.byu.edu/devo/97-98/BatemanAUC98.html> (May 1999).
 22. J. N. Hwang, D. Sachin, M. T. Sun, "A Virtual Classroom for Real-Time Interactive Distance Learning," *1998 IEEE International Symposium on Circuits and Systems 3* (1998). 611-614.
 23. T. Whalen, D. Wright. "Methodology for Cost-Benefit Analysis of Web-Based Tele-Learning: Case Study of the Bell Online Institute," *The American Journal of Distance Education*, 13.1 (1999). 24-44.
 24. M. Simonson, C. Schlosser, and D. Hanson. "Theory and Distance Education: A New Discussion," *The American Journal of Distance Education*, 13.1 (1999). 60-75.
 25. C. P. Bassett, B.M. Day, C. G. Jensen, "Joint Solutions to Design and Manufacturing Problems Using Third-Generation CAD Models Distributed Via Multimedia Tools," *Proceeding of the CIRP 1997 International Design Seminar—Multimedia Technologies for Collaboration Design and Manufacturing* (1997). 79-85.
 26. S. N. Casucci, J. A. Hoeh, C. G. Jensen, "Integrated Metrology Process for Use in Collaborative Design and Manufacturing," *Proceeding of the CIRP 1997 International Design Seminar—Multimedia Technologies for Collaboration Design and Manufacturing* (1997). 286-291.
 27. K. Bischel, E. G. Harvey, A. Overman, A. A. Tseng, "Telemanufacturing and Rapid Prototyping of Engineering Components Through the Use of the Internet," *Proceeding of the CIRP 1997 International Design Seminar—Multimedia Technologies for Collaboration Design and Manufacturing* (1997). 246-255.
 28. B. F. Loss, R.F. Riesenfeld, R. D. Fish, "Distributed Design Collaborations Embedded in the Web," *Proceeding of the CIRP 1997 International Design Seminar—Multimedia Technologies for Collaboration Design and Manufacturing* (1997). 222-229.
 29. D. Spath, U. Osmer, "Virtual Engineering: Collaborative Design, Programming, Simulation and Test of PLC-controlled Manufacturing Systems," *Proceeding of the CIRP 1997 International Design Seminar—Multimedia Technologies for Collaboration Design and Manufacturing* (1997). 168-173.
 30. S. Shivananda, V. Rao, B. Venkata R, J. Gunasekera, B. Mehta, "Virtual Reality Applied to Material Processing: Extrusion Die Design," *Proceeding of the CIRP 1997 International Design Seminar—Multimedia Technologies for Collaboration Design and Manufacturing* (1997). 162-167.
 31. J. A. Falco, E. W. Kent, "Virtual Manufacturing Tools for Collaborative Exploration of Hexapod Machine Capabilities and Applications," *Proceeding of the CIRP 1997 International Design Seminar—Multimedia Technologies for Collaboration Design and Manufacturing* (1997). 148-153.
 32. K. Mori, I. Goncharenko, J. Takashita, "Remote Monitoring and Diagnostics of Machine Tools," *Proceeding of the CIRP 1997 International Design Seminar—Multimedia Technologies for Collaboration Design and Manufacturing* (1997). 43-48.
 33. B. Findley, D. Findley. "Strategies for Effective Distance Education." *Contemporary Education*, 68.2 (Winter, 1997). 118-120.
 34. J. Wittwer, "Interactive and Collaborative Distance Learning at BYU," unpublished research paper held at BYU (1999).

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