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Shekar Viswanathan, National University

Dr. Viswanathan is a Professor and Chair of the Department of Applied Engineering and Lead Faculty for Engineering Management and Homeland Security and Safety Engineering. He is the Lead for six full time and fifty two adjunct faculty members. His department offers three undergraduate and six graduate programs and has a student population of three hundred students. Dr. Viswanathan is an educator, researcher and administrator with more than twenty-five years of industrial and academic experience encompassing engineering and environmental consulting, research and development, and technology development. His career experience includes teaching at the University level, conducting fundamental research, and developing continuing educational courses.

John Watson, National University

John Watson has been a professional technologist and researcher for over 24 years.

Research/Academic: Dr. Watson teaches computer science and software engineering courses as an associate professor at National University (La Jolla, CA) while continuing research in the areas of human and machine cognition. He holds a joint doctoral degree in Education with emphasis on education technology and multicultural education from Claremont Graduate University and San

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Business: Since 2001, John Watson has been chief technologist and president of EyeCues Education Systems, Inc., makers of data-driven software solutions and web-based application services for the education community. In late 2006, EyeCues was acquired by Get Ahead Learning, LLC. In 1999-2000, he served as interim Chief Technical Officer, developing key technologies for several start-ups. He holds or has patents-pending for a half-dozen technology-related inventions. As V.P. Technology Development for AwardTrack, Inc. in 1998-1999, he managed several technical teams, developed core Internet technology, and aided in company strategy ultimately leading to the sale of the company for $75 million. In 1995, he formed Columbus Research, Inc., a software development company that produced critically acclaimed artificial intelligence, distance learning, and Internet & Intranet-based data driven applications. From 1982 through 1994, Dr. Watson was President and C.E.O. of The Quantum Leap, a software development firm. Dr. Watson has occasionally served, since 1994, as a technology expert on television news programs (like KUSI in San Diego), reporting on advances in computing and technology news.

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Dr. Evans has over 20 years of executive and senior technical management experience at 3M Company and IBM Corporation, primarily leading multidisciplinary, global technical organizations responsible for R&D; new business and market development; manufacturing engineering; quality; environmental, health and safety; and others.

Before joining National University, he acquired 12+ years of voluntary involvement with higher education, including adjunct teaching and research in engineering at the University of Colorado and formal advisory involvement in both science and engineering at the University of Texas. Other past professional and academic activities include being a founding member and officer in the Central Texas Electronics Association; past chairman of IBM’s Materials Shared University Research Committee; Ph.D. Recruiting Coordinator for IBM’s Systems Technology Division; and executive sponsor for 3M division’s student programs. He has published and presented widely in areas of surface science, electronic materials and processes, project management, and industry/university relations. He holds 4 patents and has received awards for excellence in technical innovation (IBM), technical authorship (IBM), teaching (University of Colorado), and scholarship (National Science Foundation).

EFFECTIVE INSTRUCTION OF AN ON-LINE ENGINEERING COURSE

Abstract

On-line engineering education provides a flexible and accessible alternative for busy people who want to pursue higher education. Many higher educational institutions are increasing the visibility of their traditional programs by offering on-line options. Studies have shown that student participation and motivation is different for an on-line course. There are a number of positive attributes including:

- Some students are independent learners and may be more productive on-line,
- Some personalities are apt to participate more in class discussions if done on-line, in order to overcome the fear of speaking in front of peers, and
- Motivated by busy schedule, students are able to complete coursework on their own time.

However, questions have been raised whether on-line engineering instruction can be effective as face-to-face instruction. Many academicians debate whether on-line education can effectively communicate the essence of the lecture without compromising on quality. Recent advances made in on-line education, namely course designs, and on-line educational tools, offer a full range of interactive learning environments. More and more instructors have started adapting their courses to on-line models by implementing interactive instructional designs to their courses. As a result, the quality, quantity, and patterns of communication students practice during learning appear to be improving.

This paper discusses ways to instruct on-line engineering course effectively. This paper summarizes various on-line instructional strategies with well-defined pedagogic goals, incorporation of project-based learning concepts, implementation of interactive assessment techniques, and flexible live synchronous tutoring systems. Some of the new technologies that are becoming more prevalent in on-line environment include:

- Remote labs where on-line students can participate in real-time hands-on physical experiments remotely,
- Blogs/wikis – these tools may substitute for threaded discussion, and
- Podcasting – several universities have augmented on-line courses by offering podcasts of discussions or lecture.

Pertinent details such as ways to incorporate lecture, assignments and laboratory exercises are summarized. We distinguish between synchronous and asynchronous on-line teaching. The results of our research show that on-line, with some scheduled real-time voice conferencing compares favorably with

traditional on-site programs, while still affording considerable flexibility for students and faculty. Several examples of various engineering concepts taught are explained.

I. Introduction – On-Site Versus On-line Learning

The Internet is battling its way into higher education by offering a flexible and accessible alternative for busy people who want to pursue higher education. Many higher educational institutions are increasing the visibility of their traditional programs by offering on-line options. Still, many academicians debate whether on-line education can effectively communicate the essence of the lecture without compromising on quality. However, experts affiliated with traditional programs hesitate to denounce on-line education since it's the best option for some people and the Internet has proved useful in augmenting the resources available for use in traditional classrooms[1].

Learning is naturally an active process. We learn from doing. But often when we are learning, we just sit and listen. It is viewed that higher levels of thinking are not taking place during on-line learning. How can we motivate students into higher levels of learning, and how can we get them to use this new knowledge in a meaningful way? This is particularly critical in instructing technology courses where teaching concepts followed by practical problem solving has to be accomplished on-line[2,3.] Student motivation also plays a critical role in learning. Students are often motivated by their own desire to learn a new subject coupled with a belief that the new subject will be very important, if not essential, to their survival or to success in their business. Motivation is a main driving force in adult education.[4, 5]

National University is focused on adult learners. In particular, the average age of students is 33 years. Students who sign up for National University's accelerated learning approach have done their homework on alternatives and are already self-motivated. They demand more than what is offered by the traditional college degree program. In particular they demand in-depth focused instruction, integration, team building, communication and quantitative skills, real world case studies, projects, and problems, all as integral parts of their learning process. In addition, they want the program to be efficient and accessible, considering most students work full-time. Satisfying this diverse set of wants is a challenge in today's environment, particularly in the instruction of engineering courses.

The university may respond to student learning needs with two approaches for accelerated learning: intense on-site classes, or intense on-line classes. There may be no single "right answer" even for an individual student. Each approach offers advantages and disadvantages. On-site courses may be preferred by students who learn best in a physical classroom setting. On-line courses may be preferred by students who want to choose the most optimal time during their busy schedules for their personal learning experiences, and who have the specific control to complete tasks and projects in a timely manner working alone. But these preferences may vary with the subject matter, and they certainly vary with learning styles.

The influence of learning styles on student preferences was discussed in the paper by Uhlig and Viswanathan[6]. In this paper, the focus was on tools for on-line learning. Viswanathan observed[1] that learning is a naturally active process. He comments that some believe that higher levels of thinking are not taking place during on-line learning. Whether or not this may be true for younger students, Miller, Cohen and Beffa-Negrini report[7] that "older students taking the on-line course had significantly higher final course grades than both their younger on-line and all large-class lecture counterparts." They define "younger" to be students 24 years of age and younger, while "older" is all students 25 years of age and older. They cite numerous findings that adult learners actually learn better in on-line courses than in on-site courses. Some of the reasons cited include:

- Some students are independent learners and may be more productive on-line.
- Some personalities are apt to participate more in class discussions if done on-line, in order to overcome the fear of speaking in front of peers.
- Motivated by busy schedules, students are able to complete coursework on their own time.

Schedule flexibility is a critical factor. A significant majority of our graduate students are working adults with both full-time jobs and with families. They put a high value in being able to learn when it fits their schedule. By their nature, many of these students are individual learners. As a result, National University places a strong emphasis on developing on-line courses in as many areas as possible. This can be a challenge for teaching engineering and technology courses, which have often been seen as viable only in an on-site format.

II. National University's Engineering Course Design for Accelerated Learning

As noted by Cooper[8] on-line instruction can be offered in a number of formats. Interaction among students and the instructor may be synchronous or asynchronous. National University's on-line instruction is based on the eCollege™ platform. This platform provides methods to convey mathematical, graphical, and descriptive content. It also facilitates interaction among students and instructors.

We place considerable emphasis on synchronous interaction using the iLinc System[9] from iLinc Communications, Inc. The Learn*Linc*™ component of the iLinc Suite offers the following features:

- Voice over IP (VoIP)
- Two-way audio and video conferencing
- Application sharing
- Interactive whiteboards
- Synchronized Web browsing
- PowerBoard™ for PowerPoint™ slides
- Electronic hand raising, feedback and Q&As
- Viewable class lists
- Instructor-led floor control
- View student screens
- Breakout groups
- Participation meters
- Multimedia courseware with third-party authoring support
- Group text chat

Learn*Linc*™ is used for real-time instruction and interaction with the students. This is combined with use of the eCollege™ for submission of homework. Assessments in the form of quizzes and exams may be conducted either through iLinc or through eCollege. Application sharing allows the instructor to call up applications such as a spreadsheet, document, or technical application, and share it with students. This is a useful tool during 'lecture' portion of an on-line course. For instance, in the case of a spreadsheet, students are able to see how a change in one part of the spreadsheet causes changes elsewhere in the spread sheet in real-time. In addition, students can make presentations. Interactive whiteboards and synchronized web browsing also provides for real-time multimedia interaction.

Both on-site and on-line National University courses employ an intense four-week immersion in the subject. The student spends the same amount of contact time that they would spend in a traditional university course. But these hours are compressed into a four-week span of time. These contact hours are in addition to the time required to complete assignments. For this reason, it is critical that students have a clear roadmap to follow. Figure 1 shows such a roadmap - a generic course layout for all on-line courses offered by the National University School of Engineering and Technology (SOET). A similar layout is used for on-site courses. Bourne, Harris and Mayadas have observed[10] the following requirements for on-line engineering courses:

- The quality of on-line courses must be comparable to or better than the traditional classroom
- Courses should be available when needed and accessible from anywhere by any number of learners
- Topics across the broad spectrum of engineering disciplines should be available.

The School of Engineering and Technology (SOET) courses meet all of these design requirements. They have also been designed to meet the five pillars of on-line learning described by Bourne et al[10] learning effectiveness, student satisfaction, faculty satisfaction, access and cost effectiveness.

The course outline provides the description of the course with the required learning outcomes. Spelling out the learning outcomes is particularly important for accelerated learning, so that students can understand the relevance of each component of the course to the learning outcome. In the Week-by-Week layout, learning outcomes are expanded to cover key points to be learned for each week of the course.

Course components in the Week by Week layout include Reading Assignments in the course textbook as well as other assigned reading, a set of topic lectures covering key points and related to the learning outcomes, sets of questions for discussion during class meetings and for synchronous discussion via a Voice over Internet Protocol (VoIP) chat room for the course, and a set of assignments, including both work to be done on an individual basis and work to be done in project teams.

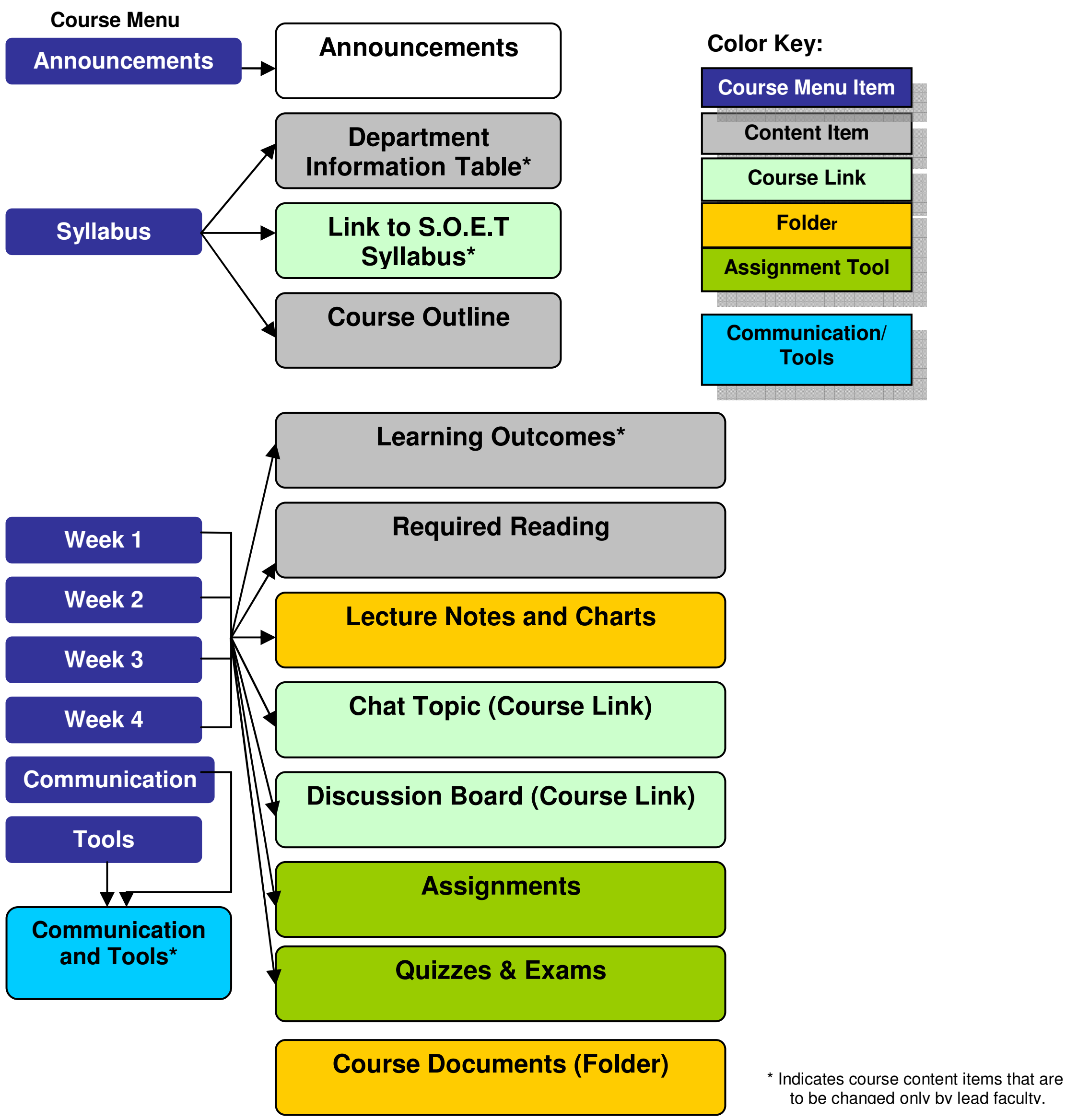

Figure 1 - National University School of Engineering and Technology (SOET) On-line Course Layout

III. National University Findings For On-Site Versus On-line Learning

National University invites every student to evaluate both what they have learned and to evaluate the teaching through survey instrument using a 5-point scale. Our findings for 28 engineering courses and for 600 students are summarized in Table 1. The data includes 17 pairs of graduate courses and 11 pairs of undergraduate courses, all of which have been taught both on-site (278 students) and on-line (322 students). Subject matter covered in these courses includes Computer

Science, Software Engineering, Engineering Management, Computer Network Security and Encryption, Risk Analysis. For this sample we find no statistically significant difference between learning and teaching for on-line and on site courses. We find a tendency for students to rate both their learning and instruction slightly lower for on-line courses than for on-site courses, although the results for on-line and on-site courses are just at the edge of one standard deviation apart. We intend to do further data collection and analysis on this issue. We find no significant differences between grades for on-line and on-site classes. This latter result differs from the results of Miller, Cohen and Beffa-Negrini[7] cited earlier.

	Student Assessment of Learning	Student Assessment of Instruction	Number of Respondents	Grade Point Average	Number of Students
28 On-line Courses					
Totals			137		322
Weighted Averages	3.86	4.11		3.13	
Standard Deviation	0.48	0.56		0.26	
28 On-site Courses					
Totals			228		278
Weighted Averages	4.24	4.52		3.16	
Standard Deviation	0.38	0.56		0.26	

Table 1 Comparison of Learning, Instruction and Grades

This data supports the notion that on-line engineering instruction with appropriate instructional technology comes close to reproducing the classroom experience for an on-site class. However, we believe this phenomenon occurs primarily when all students participate in the class simultaneously. As such, there are certain fixed gathering times each week of the course. As a result, students lose some of the flexibility of being able to choose the time when they will conduct their learning. Even with the pre-set on-line gathering times, most of the student work is self-directed.

By recording all classes we have returned some flexibility to the students participating in synchronous on-line classes. If a student must miss a class, that student can listen to the recording. The recording is much more than a simple voice recording. It reproduces everything that went on during the class. This includes display of charts presented by the instructor or by student groups, lectures material written on the shared whiteboard, and all interaction between instructor and students, both voice and text. If the instructor or any student that was given 'the floor' shared a web site with the class, that too is recorded. Everything looks the same to a student viewing the recording as it did to students participating in the live on-line class. The missing element of instruction in the viewed recording is the opportunity to interact live with the rest of the class.

One of our most important extensions to synchronous learning has been to set up synchronous "meeting rooms" where small groups of students can meet at whatever time is convenient for them to work together on small group projects. This allows students to meet and share notes, prepare presentations, discuss PowerPoint charts and see each others changes, without having to meet physically. We have had small groups working together quite effectively with some students at their office or home in San Diego, some in other parts of the US, and some students assigned to military posts in the Middle East. The recording plus the ability to share PowerPoint charts allows a student to record their part of a small group presentation in advance, if, for example, they know that they are going to be on duty at the scheduled on-line class time. This capability has proven to be very popular with students.

IV. Some Keys to Teaching Engineering Topics in On-line Classes

The principle key to effective teaching of engineering topics, or any other discipline, in an on-line format is instructor preparation. Nothing can substitute for a well-informed, well-prepared instructor. Instructors have different modes of teaching and there is no single "best" mode for instructing engineering courses. Most instructors make extensive use of PowerPoint charts, whether they are teaching a class on-line or on-site. However, even in an on-site class, it is often necessary for the instructor to use a whiteboard to clarify points on the charts or to answer questions. The on-line system used provides an interactive blackboard for this purpose. Both students and the instructor can interact on a shared whiteboard. This is particularly important for sharing mathematics that can be difficult to express in a "text only" on-line environment.

The ability to share not only the whiteboard, but more generally, to share computer applications in on-line teaching is a dramatic improvement for teaching on-line engineering subjects. For example, in some classes, the instructor may enter data in part of a spreadsheet and then invite students to complete other parts. Students can see the impact of their input on other parts of the spreadsheet immediately, and make corrections in real time, with the help of the whole class. This has proved to be a powerful on-line learning tool, and may even be superior to teaching capabilities in an on-site class. It is also a powerful interactive assessment tool. By imbedding the use of interactive tools such as shared spreadsheets, and walking through them on-line with students, the instructor is able to immediately identify areas in which more instruction is needed. This is better than finding out that students have not understood an important concept only when they take the final exam.

Data visualization tools such InspireData™ from Inspiration Software, Inc.[11], mathematical tools such as MATLAB®[12] and simulation tools become even more powerful learning and real-time assessment tools when the simulation experience is shared among students in an on-line engineering course.

National University instructors frequently include links to references in PowerPoint charts. They sometimes use web site sharing in on-line classes to look at references together and discuss them. This approach not only stimulates thinking; but it also encourages students to search and share relevant websites with the instructor and the class. The result is increased interaction among the students and the instructor, and learning is enhanced. Web site sharing is also used by instructors on a planned basis, to demonstrate key concepts from a well-designed external web sources. Visiting a shared web site can be similar to a field trip.

Often field trips are used with on-site courses to enhance learning. For example, students in Master of Science in Wireless Communications made a visit to the Major Switching Center (MSC) and local Base Transceiver System (BTS) of a major wireless communications service provider in San Diego. It would be difficult to replicate the complete learning experience on-line from this two-hour field trip. But, a considerable amount of this experience can be provided through guest lecturers. In order to supplement this experience, on-line classes have included guest lecturers from government agencies and companies. These subject matter experts provide a wealth of information relevant to the topic of discussion thereby enhancing classroom learning. Our experience indicates that students were able to interact with very knowledgeable individuals, both in real time, during synchronous on-line classes, and asynchronously after the class. We have found it somewhat easier to arrange for guest lecturers for on-line classes than for on-site classes. There is no need for the guests to travel to the classroom. They are able to give their talks and interact with the students from their office or their home, using an office or personal PC. And we have found that they are willing to answer email questions from students, even after the class is over.

V. Evolution Of On-line Learning For Engineering Courses At National University

Based on our experience, National University is now moving on to create a synthesis of the best features of live synchronous on-line classes with the best features of asynchronous on-line instruction. Some of our planned enhancements include: remote laboratories, podcasting and the use of blogs/wikis.

Conduct of live laboratory experiments by engineering students is an important of engineering education. Our positive experience with small group projects has convinced us that it is quite feasible to offer laboratory experiences to on-line students. The biggest issue is that there must be a hands-on capability to modify settings on remote equipment being used by students in a remote lab experiment. A considerable amount of work has been done in this area during the past decade, and reports have been positive. For example, in their paper, Bellmunt, Miracle, Arellano, Sumper and Andreu comment[13] that, "remote laboratories are increasingly being considered as a serious alternative to the classical local laboratories; therefore, they are being used by many institutions worldwide." They find their own results encouraging and report that the reaction of the students is favorable.

A large-scale example of remote engineering laboratories is the iLabs initiative, which started at MIT in 2000 and has been building momentum over the past 6 years[14]. Sponsored by Microsoft Research, the academic research arm of the software company, this initiative is to design and implement physical engineering experiments that can be accessed over the Internet from a web browser, thus allowing engineering educators and students to conduct experiments from remote locations at any time.

An example of and iLab experiment is a microelectronics device characterization test station where students can take measurements of the current/voltage characteristics of transistors and other microelectronic devices. Other iLab experiment stations include: a dynamic signal analyzer, a heat exchanger, a shake table, and a polymer crystallization lab. As of December, 2006, iLabs has been used in for-credit course assignments by over 4,500 students worldwide[15].

Part of the iLab project at MIT was to develop and disseminate the technology for facilitating these types of labs. MIT developed a software kit of reusable modules and a set of standardized protocols and web services referred to as the iLab Shared Architecture. This software framework has now been used by several groups worldwide to develop new iLabs. Planning is underway at National University to either join the iLab consortium or build a few remote, browser-controlled labs for use with on-line engineering courses.

University of California-Berkeley, Stanford, Harvard, Princeton and Yale, to name but a few, have stepped into the podcast game. There are two dominant categories of podcasts being produced by universities, audio from class lectures and various speeches or interviews. The lecture podcasts appear to serve the greatest utility for engineering students in specific classes, offering a portable version of a lecture that students may download and play on MP3 players, like the Apple Computer iPod. Where the upside is portability, the only downside is that most podcasts are audio only, and as such, any visuals included in a lecture would be lost. When on-topic, noteworthy speech and interview podcasts can enhance instruction and on-line curriculum. For instance, Yale University has a series of podcasts which are based on presentations in their 'In the company of scholars' lecture series. One of these is the presentation on where the biomedical engineering field is heading. If an instructor hears that the presentation includes a discussion of how detecting certain chemicals in the air is an important emerging market, it may be a perfect fit to augment a discussion of the same topic in a graduate-level engineering course.

Many university podcasts are available for free. The *Podcasting News* website[16] has a wealth of information available on free podcasts from many major universities. The Productivity 501 website[17] lists "145 free university lecture podcasts" from a wide variety of universities. They also note that MIT "allows access to lectures on-line, although not podcasted." Most university podcast download sites also offer students the opportunity to blog about the lectures (or anything else).

Our experience with recording synchronous on-line classes combined with experience in allowing students to view recordings on such classes has convinced us that it is quite feasible to break up recorded lectures into "bite-size" components that busy students can view at any times that are convenient for them. iLinc allows editing of the recordings. This makes it possible to divide a lecture into multiple segments and then make those segments available according to a menu of selections. It is a simple extension to go to the next step of making it possible for students to download these segments into portable devices, or to receive live "podcasts" of the recordings. With this capability, students can more easily review a lecture or go back and forth in a recording to review an area they may be struggling with. Eventually, we will be able to connect specific podcasts with individual learning objectives, making it easier for students to navigate through all material in the order that is most natural to them.

By combining podcast lectures with small group projects, our students will still be able to meet and work together to discuss and apply the concepts they have learned, and develop small group presentations. These small group presentations will be made available as podcasts. We will then ask the whole class to come together synchronously to interact on the subject covered by the podcast, but such synchronous meetings will be much shorter than a full synchronous class. Alternatively, interaction can be done asynchronously through blogs and wikis.

VI. Conclusions

Based on analysis of data from 600 students in 28 pairs of courses taught both on-line and on-site, we find no statistically significant difference between learning and teaching for on-line and on site courses. We find a tendency for students to rate both their learning and instruction slightly lower for on-line courses than for on-site courses, although the results for on-line and on-site courses are just at the edge of one standard deviation apart. We plan further exploration of this issue. We find no significant differences between grades for students in on-line and on-site classes. This supports our contention that on-line engineering instruction comes close to reproducing the classroom experience for an on-site class. However, we believe this phenomenon occurs primarily when all students participate in the class simultaneously.

It is critical that students have a clear roadmap to follow in on-line engineering courses. NU courses have been designed to meet the five pillars of on-line learning described by Bourne et al[10]: learning effectiveness, student satisfaction, faculty satisfaction, access and cost effectiveness.

The principle key to effective teaching of engineering topics, or any other discipline, in an on-line format is instructor preparation. Nothing can substitute for a well-informed, well-prepared instructor.

Data visualization tools such as InspireData™ from Inspiration Software, Inc.[11], mathematical tools such as MATLAB®[12] and simulation tools become even more powerful learning and real-time assessment tools when the simulation experience is shared among students in an on-line engineering course.

By imbedding the use of interactive tools such as shared spreadsheets, and walking through them on-line with students, the instructor is able to immediately identify areas in which more instruction is needed. This is better than finding out that students have not understood an important concept only when they take the final exam.

One of our most important extensions to synchronous learning has been to set up synchronous "meeting rooms" where small groups of students can meet at whatever time is convenient for them to work together on small group projects.

An additional positive outcome of our work is that some innovations developed for on-line classes, can also be applied to on-site classes. We recently invited a guest lecturer in Chicago, who had spoken to an on-line class, to speak to an on-site class in San Diego. We used the same Learn*Linc*™ software that we use for on-line classes in the on-site classroom, and projected the computer screen for the students in the on-site class.

By recording of on-line classes we have returned some flexibility to participating students. But we are going beyond this to create a synthesis of the best features of live synchronous on-line classes with the best features of asynchronous on-line instruction. And we are working to further enhance on-line class offerings. Some of our planned enhancements include: remote laboratories, podcasting and the use of blogs/wikis.

Our positive experience with small group projects, coupled with research done elsewhere, has convinced us that it is quite feasible to offer laboratory experiences to on-line students. By combining podcast lectures with small group projects and remote laboratories, our students will still be able to meet and work together to discuss and apply the concepts they have learned.

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