Active Learning Courses on the Cutting Edge of Technology

Marlin H. Mickle[1], Larry Shuman[2], Michael Spring[3]

Abstract - This paper discusses providing an active and cooperative learning experience in a cutting edge area where textbooks either are not yet available or if available, the coverage is insufficient. Specifically, the course described is in wireless computer networks; students from several disciplines must deal with a wide spectrum of device types as they also learn how technological advances have affected past and current directions in products and services. The active learning approach motivates students to ask questions immediately or prior to the next class in order to clarify gaps in understanding. The active learning concept is based on "vocabulary increasing rhetoric"; i.e., "you really do not own a word unless you can use it correctly in a meaningful sentence or context." Here, the premise is that you do not really learn the material until you can explain it to yourself through text that will be critically read thus also benefiting technical writing and teamwork skills. The course has now run successfully for two years.

Index Terms - active learning, technical writing skills, virtual laboratory, wireless communications

OVERVIEW

This paper describes providing an active and cooperative learning experience for courses involving cutting edge technologies where textbooks are not yet available or where the coverage in existing texts is too general or in a narrow or highly focused area. In these areas the dynamics of technological innovations make it extremely difficult for even the most responsible and responsive textbook companies to maintain current texts relevant.

The course considered here is concerned with wireless computer networks and involves students from computer and electrical engineering learning to use numerous types of devices. A basic premise is to understand how technological advances have affected past and current directions in order to better anticipate future advances. The course begins with an overview of cellular telephones from MPS (MTS) through IMPS (IMTS), AMPS, CDMA implementations, etc. Later coverage also includes IEEE 802.11, Bluetooth and *ad hoc* networks including small device (such as *smart dust*) networks and radio frequency identification (RFID) tagging, tracking and sensing devices and networks of these devices.

Clearly, from an applications standpoint, the coverage is very broad. However, the essence of the course is concerned with the essential technological differences that make these systems possible and commercially feasible. While existing texts cover the general subject areas, the depth of coverage is typically too limited for electrical and computer engineering students with sound technology backgrounds.

Grading is based on exams, homework and an active learning component. The active and cooperative learning element requires that each student convert his/her class notes and the general class discussions into textual material in book format based on the current class activities. That is, students are required to generate a WORD document that looks and reads like a text. The more complicated diagrams are made available in digital format to simplify the graphics and figures students need for their "textbooks".

Both exams are "open book" with each student using his or her own text. The texts are turned in with or following the exams for grading. The results provide an useful perspective on the students themselves. For those who do not take tests well, this provides an opportunity for them to overcome some of their testing difficulties and to discover individual weak areas.

The intent is to provide a better in-class learning environment by having the students through effective note taking document the material discussed after each class. This approach also motivates students to ask questions to clarify any gaps in their understanding. An ancillary benefit is that this also provides a valuable writing experience. The course has run successfully for two years. Popularity has increased the class size such that additional teaching support or alternative logistic means must now be considered.

RELATED OR SIMILAR EFFORTS

The idea of not using a text book is not new. For example, laboratory courses often use a laboratory notebook containing a set of experiments that are linked by a common thread. The thread is normally woven through a series of lectures presenting the fundamental material where it is assumed that the student has not seen the material before. The active learning model being employed here is one in which the students are familiar with the basic topics from previous experiences; cell phones, wireless communications, etc., and are required to extend that knowledge.

[1] Marlin H. Mickle, Nickolas A. DeCecco Professor, University of Pittsburgh, mickle@ee.pitt.edu
[2] Larry Shuman, Associate Dean of Engineering, University of Pittsburgh, Shuman@engr.pitt.edu
[3] Michael Spring, Associate Professor, Information Sciences, spring@imap.pitt.edu

The concept of improving learning by actively engaging student has been the subject of research in the education for many years. While the current approach is motivated both by necessity and by the anecdotal feedback we receive in the classroom, there are numerous examples of support for this pedagogical approach. Some of the work that supports our approach includes that of Brown and Najork[4], Butler and Brockman[5], Hampel, Keil-Slawik and Ferber[6], Kumar[7], and Shah and Kumar[8].In a typical laboratory course, experiments are designed to enable students to "discover" a new or unknown processes, usually to verify a formula or better predict a result. In this course, the linkages or formula are filled in during the class period, which may be viewed as a type of virtual laboratory. The students are normally required to write a laboratory report that connects together the results of using equipment in the laboratory. Here, the student writes the prose that connects together the equipment viewed in the physical world. However, some parts of the real world experiment may not always be available in which case the student must use a simple internet access protocol to observe actual hardware.

The concept of linking technologies together in such a fashion is not new. In fact, the very popular and successful notebook/curriculum/experiments in the *Making Science Make Sense* [9] (MSMS) follows this pattern using real world phenomena and sets of experiments without the use of a textbook. More interesting is the fact that that material is being used in kindergarten through sixth grades.

In MSMS, it would be relatively easy to write a text(s) for the material. However, the hands-on real learning experience is compromised if the students can not see for themselves what occurs as a necessary step in understanding the concept linkages.

GENERALIZATION

Course topics involving concepts and/or hardware that are a part of everyday life may be approached in a variety of ways, three of which will be mentioned here. One possible approach is to discuss the use of technology, including its impact on society (also an ABET outcome). A second is to initiate a multiple course sequence, first going through the relevant background theory and details of how each component works. A third, and the one chosen here, is to first examine the technology and its earlier applications, discussing how engineers and entrepreneurs dealt with relevant business, political and social issues in order to achieve public acceptance and to go from devices to commercial products.

Clearly, having a text that is not only current, but one that would also facilitate using this third approach is problematic. It would be quite expensive to setup a laboratory with the necessary equipment to support such an approach. Further, scaling down of the equipment would lose the perspective.

As an example, while one could describe the creation of cell areas using simplified mathematical models and geographical shapes, the learning experience is made much more realistic by pointing out the location of cell antennas on local buildings and towers. We propose that it is a better learning experience to have the students ask, "Why are the antennas on the *XYZ* building shaped that way?" rather than rigorously derive the electromagnetic theoretical relationships that relate wavelength to reflector distance from a dipole. This is especially true, is the end result of the course is to have the student develop functional product designs.

Obviously, the enthusiasm for this particular approach does not apply across an entire curriculum. However, as we struggle in a highly competitive business environment, it is sometimes necessary to relate what we make and how the context fits into the world we live in based on tangible working examples in *context* rather than in *text*.

Wireless communications permeate virtually every facet of daily life replacing traditional wired mechanisms while extending the scope of communicating entities to everything from appliances to grocery products to humans themselves. The popularity of wireless technology courses makes it impractical to run more traditional laboratory sessions. The cost of duplicating the available equipment to provide enough stations for students is too high at this time. Instead, we propose three solutions: (1) mini websites that provide a multimedia exposition of the relevant technology, (2) software demonstration experiments, and (3) remote access to laboratory experiments and demonstrations.

HOW IT WORKS

Analysis and design of wireless systems requires well-prepared graduates, since the subject area is rapidly developing and evolving. Students must possess an interdisciplinary background and understand the basic physics, hardware architectures, environmental impacts, distributed system principles, database design, modular programming, security and robust programming in non-deterministic environments. The Department of Electrical Engineering at the University of Pittsburgh offers a Computer Networks course (EE/CoE 1150) that covers the underlying physics, technologies and concepts that form the basis of these ubiquitous wireless devices and systems as well as the design of products that utilize wireless concepts. Complementary courses are offered by the Department of Information Science and Telecommunications in Networking (IS 1004), Client

[4] M. H. Brown and M. A. Najork. "Collaborative Active Textbooks: A Web-Based Algorithm Animation System for an Electronic Classroom"; In Proceedings of the IEEE Symposium on Visual Languages (VL'96) (pp. 266-275). 1996.
[5] J. E. Butler and J. B. Brockman. "A Web-based learning tool that simulates a simple computer architecture"; SIGCSE Bulletin - inroads, vol. 33(2), pp. 47-50. 2001.
[6] T. Hampel, R. Keil-Slawik, and F. Ferber. "Explorations - A New Form of Highly Interactive Learning Materials"; In Proceedings of the WebNet'99, World Conference of the WWW and Internet (pp. 463-468). AACE. 1999.
[7] A. N. Kumar. "Learning the interaction between pointers and scope in C++"; In Proceedings of the 6th Annual Conference on Innovation and Technology in Computer Science Education (ITiCSE'2002) (pp. 45-48). ACM Press. 2001.
[8] H. Shah and A. N. Kumar. "A tutoring system for parameter passing in programming languages"; ACM SIGCSE Bulletin, 34, 3 (2002), 170 - 174.
[9] http://www.bayerus.com/msms/index_flash.html

Server Systems (IS2550), and security (TELE 2820) covering other aspects.

In such courses at the cutting edge of rapidly developing technologies, textbooks are generally not yet available and the existing literature is either too general or narrowly focused. Technology dynamics in the area of wireless communication devices and systems are such that it is difficult for authors and publishers to maintain current relevant texts.

It is difficult, but possible, for the instructor to maintain a focus and keep abreast of developments that actually do occur while the course is being offered and to maintain good current and relevant lecture notes. However, students seldom have the *warm blanket* afforded by a text for the course.

Typically, in an engineering or information science curriculum, it is possible to identify those foundation courses that will provide the underlying physics, chemistry, statistics, algorithms and mathematics. In an area sometimes traditionally thought to be highly dynamic, these core courses could provide the basis for a somewhat stable curriculum - at least over a few years. However, the dynamics here are such that these fundamental courses and topics would need to be changed on a regular basis. This condition is difficult to administer and best to avoid if possible. Thus, it is best to build on the existing courses and try to adapt within the active learning course.

Wireless network and device technologies constitute engineering and software systems where fast moving developments result in a moving target for specifying scientific and engineering prerequisites. As long as the instructor is willing to perform the *fast footwork* needed to stay on top of the course, it is possible to keep the lecture notes and coverage up to date. How to translate this knowledge into materials that provide appropriate student support is a more difficult matter. Below we demonstrate a model that could be used by other faculty in similar situations for developing a set of material.

As noted, our way to compensate for not having a course text is to require the students to daily convert their notes into a textbook format. This requires them to at least explain their notes to themselves while the material is still fresh in their minds. Further, by engaging students in the critique of these lecture notes and supplementary materials, additional learning occurs. Hence, the basis for the active learning aspect of the course is a system of note taking and critiquing experiences. We call these student generated pieces of text "textlets." Having students reflect on and write about what they are learning has numerous benefits. First, it provides yet another opportunity to involve technology oriented students in writing exercises; especially one that makes sense to technology-oriented students. Second, it provides immediate feedback to faculty about what students are learning in lectures. We know that we do a better job of teaching a course the second, third or fourth time. Unfortunately, in an area of rapid technological change, the course is changing with every offering. We need to get feedback about the new concepts that are being taught while it is being taught so that adjustments can be made. Third, it has been our experience that learning can be greatly facilitated by giving students targets that consist of the work of prior students. This provides a bar that each succeeding group works to exceed. The fact that the technological environment is changing makes this a very desirable approach – i.e., in a static environment, students might simply copy prior work. In a dynamic environment, there is always more to do. (For example, web site architecture and design expands in scope each year. For example, this year, techniques for preventing email address harvesting are added as an important new feature that was not a concern last year.)

The students' textlets are written in WORD, and are read and evaluated by the instructor and graduate student assistant. Both give a grade on the textlet based on an agreed upon set of criteria. The two grades are then averaged to give the student the final grade. The students can then use their textlets as an aid in the open book exams.

WHAT IS NEW NEXT

The above procedure has been quite successful. However, success means that the course has become popular to the point where it is no longer feasible to handle the logistics for the large class sizes. Thus, a better methodology is required to handle the concept and implementation without changing the fundamental method of teaching the course and assigning the technical writing.

One of the co-authors (Spring) developed collaboration software that allows international standards developers to work together on the development of standards. That system is called CASCADE (Computer Augmented Support for Collaborative Authoring and Document Editing.) More than 1000 students have used the system in traditional and active learning projects. It is currently being used jointly by engineering and information science undergraduate and graduate students in an active learning experience designed to build an RFID based Role Assured Publicly Accessible Information System (RAPAI). CASCADE differs from the University of Pittsburgh's standard system (CourseInfo) in that it allows a much wider range of roles and protections on information and provides a much higher level of augmentation for communication and editing.

We feel that CASCADE can be used to enable us to deliver the course to larger class sizes. In this proposed format students would still translate notes to text. This will require thought about the flow of presentation and the linking of figures and other illustrations. CASCADE will allow others to comment on and critique the work in a very efficient and convenient form. (One of CASCADE's most developed features is an augmented system for commenting and comment review that allows a comment to be inserted with a single click. Who made the comment, when they made it, and what it is about are all handled automatically by the system. CASCADE makes it possible for a faculty member to review the comments made by students over hundreds of documents comprising thousands of pages in a matter of seconds via automatically provided dynamic hypertext representations. (The CASCADE system has its own website – http://www.sis.pitt.edu/~cascade)

Complicated diagrams and graphical representations can be posted by the course team in CASCADE. This will relieve students of the need to do an excessive amount of artwork that would overshadow the active learning aspect.

The instructor will not focus on grading these *textlets* on the basis of grammar for somewhat obvious reasons – although a comment category for grammar will be included as feedback for students. The work will be judged on the basis of the insertion of relevant descriptions and verbiage to show the flow of the material as it is presented in class. Comments on the material will be made on an ongoing basis using CASCADE's review facilities so as to maximize the timeliness of feedback. Grading of this material will be done twice during the course by both the instructor and the teaching assistant with the grade given being the average of these two results. The *textlets* will count for 25% of the final course grade and will become a part of the ongoing material used by other students in subsequent offerings. This is a standard mode of operation for some of the cutting edge courses developed by Professor Spring using CASCADE. Further, all of his courses present students will lecture notes, code fragments, PowerPoint slide sets, standards, reference materials, and samples of student work.

A VIRTUAL LABORATORY ENVIRONMENT

The popularity of wireless technology courses makes it impractical to run typical laboratory sessions. As was discussed earlier, the laboratory has been "turned inside out" in order to take advantage of the real world that the students are all living in. However, there are still some technical details to which they have not been exposed. These details can be handle by making them available over the web with some control by the student to see a demonstration as opposed to a classical laboratory experiment. Three possible ways to enable students to best learn concepts are:

1. Develop mini websites that provide a multimedia exposition of the relevant technology. This works well for laboratory sessions that are primarily directed at developing high-level cognitive appreciation of the technology and can be more effective than hands on experiments that would fail to highlight the important concepts. Samples of such sites have already been developed in Information Science for standards and distributed systems. New experimental sites are currently being developed in the security area.
2. Develop software simulations of experiments. This is particularly effective when the desired learning would generally not be visible or if made visible would be too subtle for most students to notice in the context of signals and data that detract from the main effect. Experiments of this nature have been developed related to buffer overflow impacts and wireless network configuration.
3. Develop remote access experimental equipment. That is, connect some of the existing equipment to a PC/Server in order to allow the students to conduct a number of experiments using RF equipment connected over the internet. This would allow students to gain access to a set of experiments on a 24/7/365 basis to actually see the screen responses for a variety of tests or experiments that could be remotely controlled from a PC keyboard.

Although we will use all three techniques as appropriate, it is this third area that will be the focus of the virtual laboratory to be developed as the next step in the process. Although the list of experiments is not complete at this time, a few illustrative examples are included here. In addition to the descriptions given for each individual experiment, it will be possible to view the experimental set-up using an internet-ready camera.

Experiment Example #1: The classical Active Remote Sensor (ARS) for reading the temperature from a device containing no power or connecting wires has been available for a number of years. The experimental set-up can be characterized by two systems. The first is the RF energy supply and a communications receiver. The second is the ARS device itself. It is possible to activate the RF energy supply remotely and to read the transmitted temperature of the PC screen.

Experiment Example #2: Our laboratories contain a number of commercially available RFID readers and tags. On a remote command, the tags can be moved at a number of selectable rates with the reader output (screen) being remotely displayed for the student to view.

Experiment Example #3: The ability to "focus" RF energy to form the cell geometry of our currently available cellular phones is enabled using a number of different types of reflectors for a given antenna with a fixed power. It is possible to remotely provide RF power to a transmitting antenna that can be "focused" through a number of reflectors. The effect of changing reflectors at a receiving antenna (representing the fixed cell) by observing the amount of power received.

Experiment Example #4: In the transmission of RF energy, one of the controlling factors on the distance a given level of power can be transmitted is the frequency of the RF signal. This highlights the physics/mathematics presentation in class. By using a fixed receiving antenna (again representing the mobile) it is possible to transmit at a number of different frequencies whereby the student can correlate the frequencies (wavelengths) to the given power level and the received power.

Experiment Example #5: Most courses dealing with RF communication at some point or other discuss the spectrum of the transmitter with an idealized picture to convey the concept to the student. However, in reality there are numerous variations of the shape and the actual spectrum when measured as a receiver might see it when there is noise added. In this experiment, the Spectrum Analyzer would be visible along with a collection of transmitter/antenna combinations that would be available for observation and selection.

The primary work to be done to produce the above remote experiments is to set up the necessary interface to the PC/network. In other words, the sustainable part of this component of the effort would be the interface from which a wide variety of experiments could be remotely observed.

STUDENT RESPONSES

While some of the students still appreciate the *warm blanket* textbook, there have been very positive responses with regard to the note/writing process:

"Although writing the textbook takes a huge amount of time, it is a rewarding experience."

"I enjoyed putting the notes in book form ... this helps a lot."

"Typing the notes again helps."

"I liked the fact that the material presented was up to date/current engineering topics."

The course is evaluated each year by the Office of Teaching Evaluation where individual responses are compared against other courses and faculty in the School of Engineering. Two questions in this survey come into play in the context of this paper. The first involves the "maintaining of a good learning environment". In the last two years, the positive response was 4.39 vs. 4.16 well above the 75th percentile, which is the 75th percentile (the highest breakout in the survey). The same is true for the second relevant question regarding "stimulated my thinking", which again was well above the 75th percentile, 4.09 vs. 3.93 which is the 75th percentile.

SUMMARY

The primary goal of this project is to provide the materials and methodology to support students in converting in-class notes to readable and understandable text type material to improve comprehension, provide peer support in preparation, and help in the development of better writing skills for the students.

Based on the evaluation results from the student responses, we feel that this goal is being accomplished currently as the course is currently being taught.

A secondary goal is to provide a means for students to access remote demonstrations and experiments via the internet without requiring open laboratories and graduate student supervision.

The primary impact will be a mechanism to cover highly dynamic cutting edge technical courses without settling for a textbook that is inadequate, narrowly focused, or inefficient due to coverage outside the normal scope of the course or at lower level.

While the proposed methodology does rely on computer software and hardware, the requirements are well within what can be expected to be available well into the future. This type of undergraduate course is usually supported by a teaching assistant who can assist the instructor with the minor mechanical issues involved.

The first criterion for success is the ability to produce a set of textlets that can be successfully passed from one class to another. A second criterion will be a favorable response to the proposed methodology on the standard student evaluations conducted at the end of the course. A third criterion is positive acceptance by the ABET visitors at the next accreditation visit.