Technology + Innovation = Pedagogy

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This paper presents examples of innovative technology use in teaching at Clemson University. It describes the curriculum modifications and pedagogical experimentation taken by faculty teaching calculus and differential equations, data structures and algorithms, experimental statistics, and contemporary literature and public speaking. The authors are members of Clemson University's ongoing Laptop Faculty Development Program, which supports efforts of faculty to design and develop versions of existing courses to utilize laptop computers in the classroom. This paper highlights where the approaches were successful. It concludes with results of an assessment survey administered at the close of fall 2002 and spring 2003 semesters.

Introduction

Clemson University's pilot laptop program ran from fall 1998 through spring 2002 and resulted in a phased plan for all students to arrive on campus with laptop computers beginning in fall 2002. During the pilot, selected faculty members designed, developed and taught laptop sections of existing courses. That effort increased in summer 2002 through the creation of the Laptop Faculty Development Program and the awarding of laptops to 57 faculty members representing all five colleges. An additional 40 laptops were awarded to faculty in 2003-04.

At the close of the fall 2002 and spring 2003 semesters, the Laptop Faculty Development Program administered a survey of laptop faculty members and their students. The survey results provide insights into laptop pedagogy and implications for action to improve the laptop program for both faculty and students.

Studio Calculus III, Differential Equations, and Linear Algebra

Fall 2002, William Moss began redesigning three sophomore mathematics courses: calculus III, differential equations, and linear algebra [6]. The redesigned courses are taught in a reduced lecture or studio format and make heavy use of the computer algebra system Maple, which is available on each student's laptop.

Calculus III involves the construction and study of 3D vectors, space curves, surfaces, and solids. The solutions to systems of differential equations are typically families of space curves. With pencil and paper, visualization is tedious to impossible. Moss added a visualization component to both courses by using tools built into Maple. Linear algebra is the foundation for the study of linear differential equations, the main topic in the differential equations course. Maple provides tools for going well beyond the usual pencil and paper linear algebra problems.

Moss' studio course design is based on a learning cycle with four phases: engage, investigate, reflect, and apply. The *engage* phase is implemented in an introductory 10-15 minute mini-lecture, which allows students to make connections between past and present learning experiences. In the *investigate* phase, students are introduced to new mathematical concepts and are challenged to solve problems. Contributing to this phase is the study of the lesson's main mathematical points in a Maple tutorial. In the *reflect* phase, students think about how what they have learned fits into what they already know. It is in this phase that students take ownership of their new knowledge. Contributing to this phase are low-stakes quizzes, team discussions, and questions and reflections written in the course journals. In the *apply* phase, students make connections between their new knowledge and concrete science and engineering problems. Students are far more likely to retain their ideas and concepts when they see connections to the physical world. Contributing to this phase are the team projects, the applied course journal problems, and the applied Maple tutorial problems. Moss spends most of each class period coaching students individually and in small groups. An undergraduate assistant grades the student journals during class and grades the Maple tutorials out of class.

Animating Computer Science Data Structures

Data Structures and Algorithms is typically the third computer science course taken by computer science majors at Clemson University. It is also required in computer engineering and science degree programs. This foundational course is a pre-requisite for most junior- and senior-level computer science courses. Students are introduced to a number of data structures which are software components used in large programs. Students learn the behavior of each structure, analyze its complexity, develop code implementing the structure, use the code in small applications, and learn to mesh different structures in large applications. In short, a data structure is a building block used by a developer in a large software project. Finally, data structures are dynamic, typically starting out empty and growing and shrinking as the software application executes. Since fall 2002, Roy Pargas has been redesigning the manner in which this course is taught. Changes were introduced in pilot classes and assessed [2,5]. Starting in fall 2003, major changes were made to the entire course.

Through spring 2003, students were distributed into several lecture sections, each with a maximum capacity of between 30 and 45. A student was also assigned to one of several lab sections, each section allowing at most 20 students. The lecture sections met three hours a week and were taught by the instructors; lab sections met for two hours once a week and were taught by the lab teaching assistants (TAs).

Since Fall 2003, all students are enrolled in the same lecture section and lab section. Both lecture and lab are taught by Pargas assisted by two graduate teaching assistants. Every student is required to bring a laptop computer to each lecture and lab session, which gives the instructor and teaching assistants great flexibility in organizing the manner that course material is taught.

Before coming to lecture, students take a short online self-assessment quiz. The instructor reviews the results and can adjust the lecture accordingly, addressing specific weaknesses identified by the quiz. The first thirty to forty minutes of class is devoted to lecture, always accompanied with some form of animation demonstrating the dynamic characteristics of the data structure being discussed. The students download the animation and any other course material for the day and work with the material as the instructor lectures. The students learn the behavior of a data structure by manipulating it on their laptop computers, not merely by listening to the instructor describe it. An excellent example of this type of animation is demonstrated in an applet developed by Gogeshvili [4] to illustrate the behavior of several tree-based data structures. Applets such as this are used extensively in this class.

After the lecture, a carefully structured laptop exercise (lex) helps the students uncover subtle but important behaviors from the data structure. Students are encouraged to collaborate with, and learn from, one another. At the end of the lex, students answer questions and submit them through a web-based course management system. A weekly lab exercise is designed to strengthen the students' programming skills and ability to analyze algorithms. Finally two tests and a final examination, all online, assess students' retention of the course material.

Microsoft NetMeeting in the Classroom

For several years, Lawrence Grimes has successfully used Microsoft NetMeeting, especially the whiteboard feature, with his experimental statistics students. The features, as described below, allow a lot of flexibility in presenting and preserving material and in communication with and among students. This, in turn, enhances the quality and clarity of presentation and the overall learning experience according to course evaluations.

Microsoft NetMeeting is free software that allows computer collaboration via the network (or Internet). It usually already exists on Windows computers. Available functions include a digital whiteboard, chat, file transfer, software sharing, audio communication, and video communication. While the audio and video components are only available between two computers, the other features can be involved by up to 12 computers simultaneously. Connection is achieved by entering IP addresses in the appropriate box or by the use of an Internet Locator Server (ILS). The digital whiteboard allows handwritten notes to be displayed (easily facilitated with a digital tablet such as the WACOM 12x12) and saved (using ADOBE Acrobat Distiller) for later review (for example on the class Web page). Screen captures of any software or image are easily pasted on the whiteboard for annotation. Whiteboards can be prepared in advance similar to PowerPoint. All students collaborating in a class can be allowed to write on the whiteboard or they can be prevented. Grimes uses the whiteboard in place of a chalkboard to display lecture notes, to work through problems, and to aid in demonstrating (through annotation) various software. Students can work on the whiteboard as though called to "go to the board and work a problem" even when they are not physically present in class.

Software sharing allows one member of the collaborating class to open an application (not necessarily available on all the computers) in such a way that it can be viewed simultaneously by all other members of the group. Control of the application can be shared one at a time with other students. This facility is excellent for training, demonstrations, and document collaboration. For example, Grimes can have a student work through the solution of a statistical problem using MS Excel while the rest watch. Mistakes that are made can be pointed out quickly so that corrections can be made in a timely manner. Occasionally, he has put students in pairs and had them collaborate in NetMeeting sessions working through a statistical problem. Using a computer headset, pairs of students can talk (even have video if there are cameras) while they work together. This can be done from anyplace where there is Internet access so there is the capacity to do this without coming to the lab or class.

The chat component works similar to other commonly used chat software and allows students to send messages to the entire class or any particular student. The file transfer tool is reasonably easy to implement.

Written, Oral and Digital Communication

Teaching English and communication studies courses in a laptop environment freed Barbara Weaver to move beyond the traditional boundaries of the classroom to explore possibilities with other faculty and her students. Some of her successful laptop assignments are cross-discipline projects that allow the students to apply their written, oral and digital communication skills.

For example, in her contemporary literature class, Weaver's students used class time to plan, develop and rehearse a program associated with Arts in April, a campus-wide focus on the arts. Their program began with a concert by Clemson professor Linda Dzuris's carillon students followed by the literature students' multimedia presentation on the Beat poets. In researching the topic, students used many online sources and a Public Broadcasting System (PBS) documentary [1]. Their class presentation ran on one student's laptop and was projected onto a large screen in the amphitheater. From invention to post-project review, Weaver coached her students to discover and claim their knowledge of the course content.

In a public speaking course, Weaver used a project with the S.C. Botanical Garden Sculpture Program. The students designed, developed and delivered multimedia presentations on the current year's sculpture to elementary school children. The students helped the artist install the sculpture and documented on their laptops and with digital cameras their observations of the process. They traveled to the schools to deliver their presentations designed specifically for the children. Each presentation was digitally videotaped and uploaded to Clemson's network so students could watch their presentation on their laptops to gain a better understanding of their skills. Weaver and her students are included in the documentary series *Touch the Earth,* which tells the stories of the artists and the student involvement [7,8,9]. Weaver's students reported they gained more from the workshop environment in the classroom and the authentic project than from lectures and giving speeches to their classmates.

Conclusions: Laptop Faculty Development

At the close of fall 2002 and spring 2003, the Laptop Faculty Development Program [3] administered a survey of laptop faculty members and their students. The survey results indicate that faculty and students agree that using laptops in class increases student engagement and learning without hindering student-faculty interaction or increasing student workload.

The survey also reveals that attendance at laptop pedagogy workshops, a willingness to change teaching styles, and having time to prepare to teach with laptops in the classroom all directly affect the success of the course. Two Laptop Faculty Development Program offerings are especially helpful. One is small interdisciplinary faculty communities that meet weekly for one hour to explore laptop pedagogy. The other is Visit a Laptop Class through which faculty observe laptop classes taught by experienced faculty. Clemson University is continuing to provide faculty opportunities to develop laptop courses and is continuing assessment of the program.

References

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