

AC 2008-1101: TEACHING A HANDS-ON BIOMEDICAL INSTRUMENTATION COURSE JOINTLY AT TWO INSTITUTIONS

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Teaching a hands-on biomedical instrumentation course jointly at two institutions

Abstract

The Biomedical Engineering (BME) department at the University of North Carolina at Chapel Hill (UNC) has taught a microcontroller applications course for many years. In this course, students learn how to program a microcontroller and interface it to hardware to develop biomedical instruments, such as a heart rate monitor and temperature sensor. With the development of a joint BME department at UNC and North Carolina State University (NCSU), the faculty realized that it would be beneficial to teach the class jointly at NCSU, as the students there needed more hands-on opportunities in biomedical instrumentation.

The class meets twice each week using videoconferencing equipment. Both classrooms are equipped with multiple screens for viewing video of the distant location, as well as sharing a computer desktop. Students work in the laboratory on weekly homework assignments and “mini-projects”, in which they program microcontrollers and develop biomedical instruments. The laboratories on each campus have equivalent hardware setups, as well as videoconferencing equipment so that faculty can help the students remotely. The primary teacher for this class is based at UNC, and he occasionally travels to NCSU to work with those students directly. In addition, a faculty member at NCSU is present for most classes, and he is available to provide assistance to the NCSU students outside of class. In this manner, the NCSU students have opportunities to get “in-person” help from a faculty member. Feedback on this experience was measured at mid-semester and at the end of the semester. This experience can serve as a model for teaching courses jointly at our universities as well as elsewhere.

Introduction

The University of North Carolina (UNC) and North Carolina State University (NCSU) formed a joint department of Biomedical Engineering (BME) in 2004. This resulted in a joint graduate program at UNC and NCSU. However, the undergraduate programs are currently separate.

Both undergraduate programs are relatively small but growing, and it is expected that the class of 2008 will have 22 students at UNC and 45 students at NCSU. Currently, the UNC program has a single “track” that has a bias toward instrumentation. The NCSU program has tracks in Biomaterials and Tissue Engineering, Biomechanics, and Biomedical Instrumentation. Because of the small sizes of the programs, it is difficult to offer a large selection of upper level BME electives that the students can choose from. At NCSU, this is compounded by the fact that the 45 students are divided into three tracks, each requiring a different set of upper level electives to choose from.

Therefore, even though the two undergraduate programs are separate at this time, having a joint department provides an opportunity to increase course offerings through joint teaching of classes at the two institutions. This helps expand the number of available BME electives to students at both institutions, and makes efficient use of faculty resources by allowing them to teach students at both institutions simultaneously. Several courses have been taught this way since 2004, using

our videoconferencing facilities, with some travel back and forth by the course faculty to provide face-to-face contact with all students. However, these were all lecture-based courses with little or no laboratory component.

There was a particular need at NCSU to offer more hands-on biomedical instrumentation courses to serve the students in that track. Because faculty were not available to create new classes at NCSU, the authors decided to extend an existing class at UNC and offer it jointly at NCSU. The Microcontroller Applications course was chosen because it fulfilled a void at NCSU and it was well established at UNC.

Challenges

Videoconferencing technology is becoming increasingly powerful and inexpensive. It allows for seamless, real-time interaction between students and faculty at two or more locations, and as a result, it is gaining more widespread use in higher education¹, even in courses with a laboratory component²⁻³. The benefit is that this technology creates opportunities for additional course offerings. However, it also creates additional challenges when trying to teach students effectively.

A detailed survey taken by students and faculty at UT-Austin shows that they have concerns about distance education that are similar to what we have seen at our institutions⁴. In our experience, the most significant challenges are:

- Students are typically less engaged when the faculty is teaching them from the other side of a television screen.
- It is difficult to deviate from traditional lecture format when you are using videoconferencing, so it's harder to use more interactive methods to help students learn the material.
- Students need opportunities for informal contact with their teacher before or after class, which helps them get to know each other personally, and allows for easy opportunities for questions on the material. Clearly this is more difficult when the teacher is on the other side of a television screen.

The fact that this was a hands-on class presented additional challenges to those described above, in particular:

- We needed to have matching microcontroller development systems, both hardware and software, in student laboratories at each institution.
- We needed a mechanism for locally-based support in the laboratory, so that students could get troubleshooting help by a real person standing next to them.
- We needed a means for faculty to provide help from afar, for those times when it wasn't possible to have a real person in the lab with the students.

Objectives

The objectives of this paper are to describe how Microcontroller Applications was taught jointly for the first time at UNC and NCSU; analyze what worked well and what didn't work well; and discuss whether this is an effective way to teach a class. What the faculty learned from this

experience will help guide us as we consider more joint courses in the future. It could also serve as a model for hands-on courses taught jointly at other institutions.

The authors of this paper were the two faculty members involved with the course. RG was the primary teacher for this class and he is based at UNC. DL was familiar with the material, having previously taught the class for 6 years at UNC. He is currently based at NCSU and served as a local contact for those students. He attended almost all of the classes and helped students outside of class with their programming assignments.

Methods

Structure of course

The basic content of this class was firmly in place for several years at UNC before the class was offered jointly to NCSU students. The overall goal is for students to learn how to implement basic microcontroller functions in order to develop simple biomedical instruments. This is an upper level elective and the students have previously taken one or more classes in electronics, programming, and biomedical instrumentation.

For the first few weeks of class, there were introductory lectures on microcontroller architecture, number systems, and languages. The rest of the semester was slightly reorganized last year into two challenge-based modules, according to a framework developed by the VaNTH ERC for Bioengineering Educational Technologies⁵.

The first module was the development of a reaction time test. It was introduced by a BME graduate student who described the physiology behind reaction time, and how those measurements are used in his research area. Subsequently, students determined what tools they needed to use in order to develop their own testing device, and these materials were covered in class during the next 4 weeks. Students had weekly homework assignments so that they gained experience in implementing the different features covered in class. These assignments involved assembly language programming and circuit development. They started out with simple tasks, such as turning on LEDs for 1 second, in response to a button press. Over the next few weeks, the assignments became more complex, incorporating LCD displays and timers. Assembly language programming was used for this part of the class so that the students gained a thorough understanding of microcontroller operation through the use of a low-level language. At the end of the module, students developed a device that measures their reaction time, and they tested it on themselves.

The second module was the development of a pulse rate meter. Much to the students' relief, C language programming was used for this module so that students were able to implement more sophisticated features in each weekly assignment. Through these assignments, the students gained experience in implementing analog-to-digital converters, interrupts, and other features. Assignments included a hearing test in which the microcontroller outputs a square wave to an amplifier and speaker circuit, and the user interacts with the device to test their range of hearing. At the end of the module, students put it all together into a complete pulse rate meter. They demonstrated their project by testing it out on themselves, running up and down the hall, and measuring their elevated pulse rate and watching it gradually decrease as they rested.

There was an additional week remaining at the end of the semester in which we had in-class development of several projects going on simultaneously in the two labs, connected by videoconferencing.

Lectures

Lectures took place twice a week using videoconference facilities available on each campus (described below). RG led each class from UNC. DL was present at NCSU to provide local support to the students. The class consisted of a mix of traditional lecture and in-class problem solving, and occasionally the students would be asked to stand up and “act out” the movement of “bits” from point A to point B.

It was clear that any deviation from traditional PowerPoint lectures would be particularly difficult given the videoconference format. However, it was also important to do whatever was feasible to try to hold the attention of the students, particularly those at NCSU who would have a difficult time staying engaged while the class was being taught from UNC. So the presence of DL at NCSU was important, as he could facilitate any in-class exercises at that location. For example, RG might ask the class to take 5 minutes to write or analyze a small section of code. This would help to reinforce the material covered in class, but it was difficult for RG to interact with both the NCSU and UNC students during this time. Therefore, it was valuable to have DL at NCSU to help the students there, and RG could concentrate on the UNC students.

It was also important to have DL at NCSU so that he could provide perspective on how things were going from that end. As noted above, any class taught through videoconferencing is difficult on the students when they do not have their teacher present locally. With DL at NCSU, he could interact with those students before and after class, and provide RG with feedback on their perspective.

Instructional technology

Instructional technology has been used in this class for many years, even before it was taught jointly. In particular, Blackboard course management software (Blackboard, Inc., Washington DC) has been used to distribute course materials and assignments, and collect completed assignment code from the students.

Additional uses of instructional technology were developed to facilitate the joint class. NCSU students were given accounts on the UNC Blackboard server so that everyone could easily access the same course information in one place. One new area of need was with sharing troubleshooting information. Students sitting in a lab together will often share information, such as –

- Your microcontroller is not working? Make sure it’s powered!
- The assembler is giving you warnings because you forgot to indent each line

However, it is more difficult for students to informally share troubleshooting tips across 30 miles of distance between two campuses. To address this problem, the instructor created a wiki on

Blackboard, and for each assignment, every student was required to enter some troubleshooting tips onto the wiki. Subsequently, students could look at this at any time, and find useful information to help them with their assignments.

RG monitored this wiki to insure that the students were giving appropriate information, rather than homework solutions. In all cases, the wiki was used effectively without any problems. Feedback from students indicated that they were reading the wiki and finding useful information there as they worked on their programming assignments.

Laboratory facilities

The PIC 16F877A (Microchip, Inc., Chandler AZ) was used for this class, as it provides an excellent platform for learning how to use a microcontrollers and many of its most useful features (timers, interrupts, analog-to-digital converters, etc). There are options available for both assembly language and C programming. The PIC assembly language consists of just 35 instructions, so it is relatively simple to learn, and Microchip provides a free assembler. Also, there is a good selection of affordable C compilers available for the PIC.

The biomedical instrumentation laboratories were used on each campus. Each lab was upgraded for the joint class to have the same microprocessor development system, consisting of the CCS PIC-C compiler, ICD-U programmer, and Software Prototyping Board (Custom Computer Services, Waukesha, WI). The Software Prototyping Board includes a socket for the PIC 16F877A, a connector to the ICD-U programmer, and switches, potentiometers, LEDs, and a breadboard for easy connection to any of the pins on the PIC. The use of the prototyping board was new for the joint class, as it minimized the hardware problems and made it easier for the faculty to help students from afar.

Each lab was equipped with approximately one station for every two students. This was sufficient to prevent overcrowding, as students worked on their weekly assignments at different times during the course of the week.

Videoconferencing facilities

The BME department has videoconferencing equipment in a number of conference/classrooms on both campuses. These rooms are used for numerous classes and meetings held at jointly UNC and NCSU, and they can interface with videoconferencing equipment at any location inside and/or outside of our department. Each room has two large screens: a 42" plasma for viewing video, and a pull-down screen and projector for viewing a computer screen. In this manner, students at each location see live video and audio of the distant location at all times, while also sharing a computer screen between the locations.

The IP videoconferencing is implemented with Polycom (Pleasanton, CA) ViewStation FX units at each location. For sharing a computer screen, each room has a standard PC, with no specialized hardware necessary, which is attached to a computer projector for viewing by the entire class. The computers are synchronized using the Oracle Real Time Collaboration suite, available free of charge to anyone with a UNC affiliation. This allows real time sharing of

computer screens via the Internet, with no special software other than a web browser needed to log in.

In order to teach the microcontroller applications class, additional videoconferencing units, identical to what was described above, were purchased for the laboratories on each campus. This was done with the intention that it would be used for additional classes in the future. With this capability, it was possible for a faculty member on one campus to be able to help students in the lab on the other campus. In addition, the lab was arranged so that a faculty member at UNC could zoom the NCSU lab camera on an oscilloscope screen, and monitor the signal measured by a student there in real time. The videoconferencing equipment in the laboratory is shown in figure 1. With this setup, it was even possible for a faculty member to connect from home or any location with high-speed Internet access to either the UNC or NCSU labs and interact with the students. All that was required is a standard PC or Mac with a web cam and free videoconferencing software.



Figure 1a and b: Shows the videoconferencing setup in the UNC lab. An NCSU student is on the video screen, showing her oscilloscope trace and sharing her C program.

Results

First half of the semester

Because the lectures were originating from UNC, RG did realize the importance of personally meeting the students at NCSU. The 30 mile distance between the two campuses made it feasible, so he made three visits during the first half of the semester. The purpose of these help sessions was to show the students how to setup the PIC development hardware and software, and to answer questions. However, it was later apparent that this was helpful but not sufficient.

In teaching this joint class, RG assumed that students at both universities would have similar backgrounds and be equally prepared. However, a few weeks into the semester, it was determined that the NCSU students had a weaker background in programming and electronics, mostly due to their experiences in those “service” classes taught by other departments. This added to the fact that they were already at a disadvantage because RG, the primary teacher for the class was based at UNC and classes originated from there.

The extent of this disadvantage did not become clear until the midterm, when the exam scores from NCSU were significantly lower than those from UNC. At the same time, an anonymous mid-semester evaluation was given out to all of the students on Blackboard to obtain more feedback on the problem and potential solutions. The results are given in figure 2.

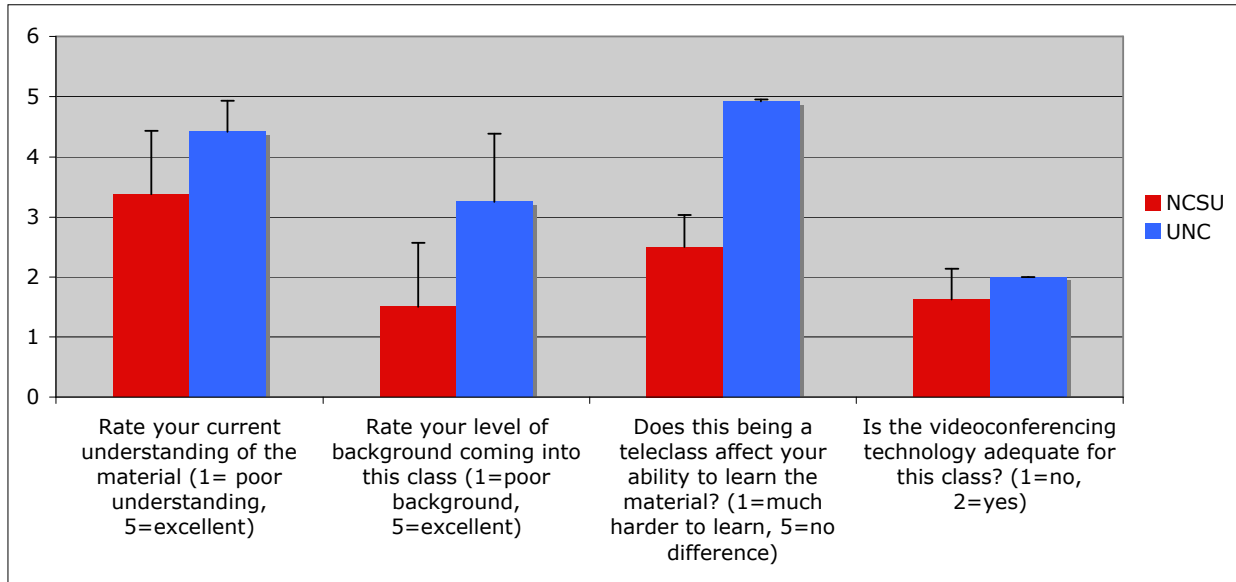


Figure 2: Results from mid semester course evaluation

From the results, it is apparent that

- The large disparity between UNC and NCSU students in their backgrounds coming into the class was significant. However, the gap was somewhat smaller by the midterm
- The effect of the teleclass was virtually non-existent for the students at UNC because their teacher and all of the lectures originated from their campus
- The effect of the teleclass was significant at NCSU.
- There was also a slight disparity in their views of the videoconferencing technology.

Also, the students were given opportunities to comment on the above questions. A representative response from NCSU was:

“I feel like we are at a disadvantage doing homework, studying for exams, etc. by not having access to the professor.... It just seems like the students on the two campuses are getting two different kinds of help. I also think that it is a problem teaching to both the NCSU and the UNC students at once because we have such different backgrounds.”

Second half of the semester

To address the problems described above, RG made adjustments to the class after the midterm. While the lectures still originated from UNC, RG traveled to NCSU each week for a “help session” at a time that was convenient for all of the students. This had a multiplying effect as once the NCSU students felt more comfortable with RG, they spoke up more in class, sought out more extra help via email and via videoconferencing.

In addition to the weekly in-person sessions, RG helped NCSU students remotely via videoconferencing at least once a week on the day before homework assignments were due. This was quite successful as RG could monitor their code remotely, and zoom the camera on the circuit and oscilloscope to create a situation that was almost as productive as being there.

The results of these changes were apparent in the quality of the work coming from NCSU students. In the final exam scores, the gap between UNC and NCSU performance had closed by more 50% since the midterm exam. In addition, NCSU students were doing better quality work on their homework assignments and projects, and completing them in shorter amounts of time.

Figure 3 shows the results from an end of semester survey that repeated some of the same questions from the previous survey.

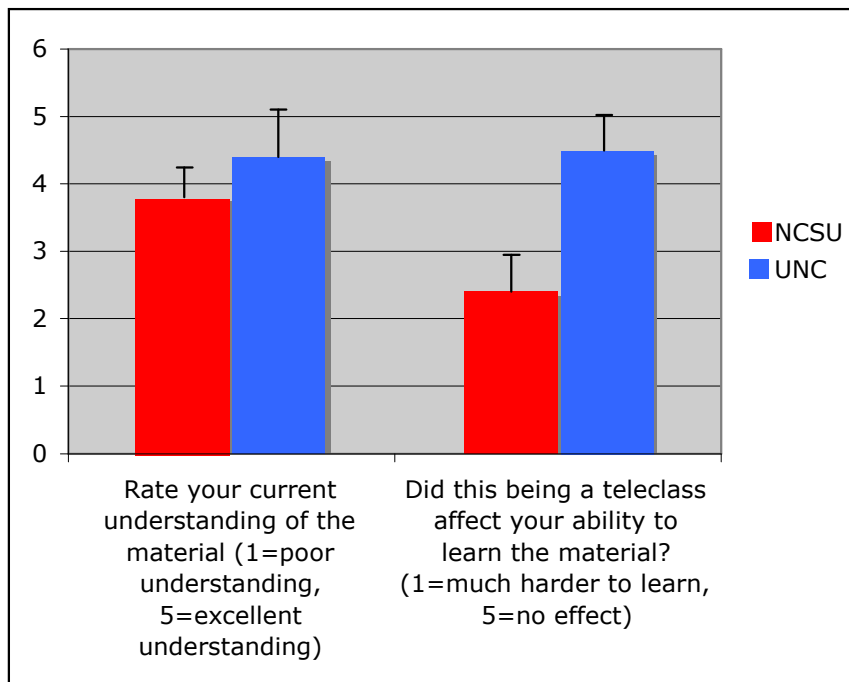


Figure 3: Results from end of semester course evaluation

Therefore, while NCSU exam scores improved significantly from the midterm to the final, they only felt slightly more confident in their understanding of the material. Also, there was a small but surprising drop in the UNC students' perception of the teleclass affecting their ability to learn the material. Follow-up comments did not provide any explanation for this change.

The following comments from NCSU students are representative:

- “It is hard to teach to students with different strengths and backgrounds much less do it 30 miles away. (I think that the second half of the semester showed a great improvement as the accessibility to the instructor was more equal).”
- “It was also a little embarrassing to ask questions in front of the UNC students since we all knew that they felt like the material was so easy.”

From additional student comments, it was clear that:

- About half of the NCSU students expressed a desire to separate the UNC and NCSU sections with a teacher based on each campus, instead of videoconferencing.
- However, NCSU students greatly appreciated the opportunity to get hands-on experience with microcontrollers, and they realized that this would not have been possible without the videoconferencing format.
- UNC comments were uniformly positive about the class

Discussion

Our first experience in teaching Microcontroller Applications jointly at two universities was largely a success. Student performance at UNC was comparable to past years in which the course was only taught at that institution. Student performance at NCSU was weaker than at UNC (7 point difference on average final exam scores), primarily for the following reasons:

- UNC students had stronger incoming backgrounds
- The primary teacher for the class was based at UNC

In order for the class to be successful, two factors stood out as the most important:

1. *The need to have a faculty member or teaching assistant present at both sites.*

For most of the semester, DL served this purpose at NCSU while RG taught from UNC. However, one day RG led the class from NCSU, leaving nobody with the students at the UNC classroom. The UNC students spent much of the class with their microphones off and talking to each other. Upon further questioning in the anonymous course evaluation, student reactions were revealing:

- “I wouldn't say that I wasn't listening or learning, but it was more difficult to keep visual contact with the tv version of you. It didn't seem as important to look up and show you that I was paying attention.”
- “Not having to worry about speaking over you, many students chose to talk during the class. Interestingly enough, much of the conversation was on the class material. We were able to clarify things with each and discuss the material. Still the talking was most certainly a distraction to some and should not have been done.”
- “If you were there, it would have definitely made a difference, and we would have been more attentive.”

This clearly demonstrates the need to have a teacher or teaching assistant (TA) in the classroom at both ends of the videoconference.

- 2. The need for the primary teacher to have in-person contact with students at both institutions. This is particularly true with the hands-on nature of an instrumentation class.*

Student feedback indicates that RG's weekly visits to NCSU in the second half of the semester were helpful. It also helped to improve interaction with NCSU students during videoconference classes and to improve performance in the class as measured by final exam scores.

Overall impressions and future changes

In spite of the improvements made during the course of the semester, some NCSU students still felt that it would be better to teach separate sections of the class at each institution. This is not surprising. However, it was clear that by teaching the class jointly, we used faculty resources more effectively and still provided an excellent learning experience for the students.

Outside of the weekly visits to NCSU and the general burden of adding students to any class, the joint class did not create a significant amount of additional work for RG. In fact, many of the changes made, such as the use of wikis for sharing troubleshooting tips, would be useful for the class, regardless of the addition of NCSU students.

As an elective class, this course is not formally evaluated as part of the ABET assessment process. Our course level assessment at UNC and NCSU is accomplished by checking student performance on select course objectives, and if necessary, it would not be difficult to perform this for a required class taught jointly at both institutions.

We intend to continue teaching this class jointly, with some changes. While DL was the local contact for NCSU students for the first year of teaching this class, in the future there will be a TA instead. The TA will rotate between UNC and NCSU, attending class in the opposite location of RG. This will allow RG to distribute his time more equally between the two institutions. The TA will also be available to help students on either campus with their weekly programming assignments and projects. This will alleviate a significant issue for the NCSU students.

In addition, 1-2 joint meetings will be held early in the semester with the UNC and NCSU students physically in the same location. This may involve an activity related to the class, or a purely social activity. In the end of semester surveys, students from both institutions were enthusiastic about this idea and expressed no hesitation to travel to the other campus or a neutral location halfway in between. To alleviate scheduling problems, the joint meeting(s) will be held in the evening. Previous experience in other classes shows that when the students have this opportunity to interact informally, it facilitates interactions during videoconferencing classes throughout the semester.

Finally, changes to the NCSU curriculum will be implemented to provide better background to NCSU students, which will greatly ease the disparity between the two institutions.

Conclusions

Our Microcontroller Applications class was taught jointly between UNC and NCSU for the first time. Overall, the experience was a success. It provided NCSU students with a new hands-on biomedical instrumentation class that, due to limited faculty resources, would not have been available otherwise. At the same time, the joint class did not affect UNC student performance compared to previous years when it was taught only at UNC.

This class was more successful because: the institutions are only 30 miles apart, allowing the faculty to travel between campuses; a faculty member was based at each institution; we have good videoconferencing facilities in the department; and we had equivalent hardware and software setups at each laboratory.

The primary challenges were that NCSU students came into the class with less preparation than the UNC students, and they had less contact with the primary teacher of the class, who was based at UNC. Future changes are being made to alleviate these problems. Our experiences can serve as a model for future classes taught jointly at our institutions, as well as elsewhere.

Acknowledgements

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