AC 2007-278: INCORPORATING STUDIO FORMAT INTO AN INTRODUCTORY MICROPROCESSOR COURSE

Jonathan Hill, University of Hartford

Dr. Jonathan Hill is an assistant professor in the College of Engineering, Technology, and Architecture (CETA) at the University of Hartford, Connecticut (USA). Ph.D. and M.S. from Worcester Polytechnic Institute (WPI) and B.S. from Northeastern University. Previously an applications engineer with the Networks and Communications division of Digital Corporation. His interests involve embedded microprocessor based systems.

Incorporating Studio Format into an Introductory Microprocessor Course

Abstract

In the fall 2002 semester I expanded an introductory microprocessor course by adding studio content and received very positive results. Studio format is a method of teaching engineering material, using cooperative learning and hands on activities. This course is a requirement for all of our electrical engineering and computer engineering undergraduate students. The course previously did not have laboratory content and in expanding the course we chose studio as an alternative to laboratory format. Unlike other uses of studio format, the lecture component was retained as-is. In this case studio is scheduled separately from the lecture component. While our scheduling of studio time is like that of a laboratory, the studio format is actually quite different from laboratory format in several ways. In particular, for an introductory microprocessors course, studio provides an effective means to get students active early in the semester. In summary, we find that studio format helps greatly in teaching introductory microprocessor topics and we are continuing to refine our use of studio format in this course.

Introduction

During the fall 2002 semester a change in the electrical engineering curriculum required us to increase the content in our introductory microprocessor course. The course is a requirement for all of our electrical engineering and computer engineering undergraduate students. The course previously did not have laboratory content. In considering how to increase the course content by one credit, to four credits, we first considered adding laboratory content, then chose to try something new and add studio content. Studio format is a method of teaching engineering material, using cooperative learning and hands on activities. With studio content, the course changed from being a bother to one that students truly appreciate.

The term “studio format” has a range of meanings attached to it in the literature. We use the term here to mean an instructor led scheduled time period that is not project oriented, using cooperative and hands-on learning techniques. Courses are often taught entirely in the studio format, combining lecture, cooperative learning, and hands on exercises. A semester outline of studio activities is given later in the paper. In talking with a colleague, I became concerned whether all the required material in a microprocessors course can be presented this way, in one semester. In being the required microprocessor course for electrical and computer engineering undergraduate students, this is a particularly important concern. With the ABET emphasis on outcomes, the course plays an important role in the overall curriculum.

Given the consideration of our expanding the course, we chose to retain the lecture component as-is and add studio content as a separately scheduled component. Other uses of studio format usually contain a lecture component in some form. I was concerned that if the entire course were to adopt studio format, there might be a tendency for the lecture component to dominate. I suspect such tendency may start as the perceived need to cover material in an overly comprehensive fashion, by presenting supporting material. In scheduling the studio component

separately, in a manner like that of a laboratory, it is our wish to simultaneously satisfy our commitment to ABET in terms of course outcomes and reduce pressure to guarantee the quality of time used in studio. While our scheduling of studio time is like that of a laboratory, the studio format is actually quite different from laboratory format.

Other schools may also benefit in scheduling the studio component separately in that it allows for one lecture to have several studio sections. In our college however, in the last five years class enrollment has varied from 15 to 23 students, so that having a second studio section is rare but is occasionally added in an ad-hoc fashion. Student feedback is collected three ways. At the end of every semester, students are given a standard college questionnaire. Given that the standard questionnaire does not ask studio related questions, a second questionnaire was written for our use with the studio format. Given that the format of the standard college questionnaire changed before the fourth offering of the course, we rely primarily on the studio questionnaire. Detail on the studio questionnaire is presented later. Feedback regarding the course also comes from the exit questionnaire that graduating seniors are required to take.

In the following we outline the overall course and our use of the studio format. Given our choice to expand the course by adding studio content rather than laboratory content, we contrast studio and laboratory content as it pertains to this course. The classroom itself plays a role in studio format and is also discussed. Finally, we assess the results.

Course Outline

We find that studio format helps teach introductory microprocessor topics. A significant part of this course involves the architecture of microprocessors. The reason for teaching assembly language is to have students come face to face with and get a feel for the actual hardware by directly using it. As Tanenbaum[3] points out, each layer in a computer system is like a virtual machine and each layer is quite different, so that what the assembly language programmer is aware of is different than that of a higher level language programmer. In a nutshell, this is not an introductory programming course. Rather, this is a computer engineering course and given the intimacy to the actual hardware, it is worthwhile to know something about assembly language. The most important lessons for students to learn in this course are the following:

- What a Von Neumann architecture[3] is and the stored program concept
- What a memory map is and common memory types
- Microprocessor addressing modes
- What the stack is and its basic uses
- What the fetch-execute cycle is and its overall significance
- How the microprocessor interacts with peripherals through device registers
- A general notion of what interrupts are
- Skills useful for performing a senior project

To present these points, I chose the Motorola 68HC11 microcontroller as it resembles a typical Von Neumann architecture. The Von Neumann architecture expounds on the stored program concept whereby executable code and data are stored together in the same memory space. The studio format is an instructor led experience where students actually use and learn about such a

processor. With the basics of the fetch-execute cycle learned and fully understood, students are more prepared to learn advanced computer engineering related topics.

Semester Studio Outline

The keys to studio format are its use of active cooperative learning and hands-on activities. As with laboratory, studio is not an extension of the lecture experience. In particular, we do not use studio as a homework help session. The use of studio format here falls into three major phases. Students first become familiar with the basics of assembly language and the software tools. Students use a tool called THRSim[1], which provides an integrated text editor, assembler, and simulator. THRSim is a relatively comfortable graphically oriented point and click type development environment. During this first phase, instructor led exercises direct students to work cooperatively to practice new skills. Students discuss and implement example programs.

In the second phase, students work cooperatively to practice skills they have learned and to encounter practical issues. In particular they learn to use peripheral devices. It is common for the instructor to outline a program by describing the underlying algorithm in words or in the form of a flowchart. Groups of students cooperate to write their own program source code. On some occasions, fine details are left for the students to discover for themselves, and when discovered are shared with the whole class. Such details may include methods to access an array of integers, or the differences in comparing signed or unsigned integers. The point is to give the students a sense that writing a program is not a cut and dried affair. There are twists, turns, and opportunities for discovery.

Near the end of the second phase, students are presented with the actual target microprocessor board. For debugging in the actual system, we use a simple resident monitor program called Buffalo which is in the actual target microprocessor. Students are assigned a series of two projects that they perform outside studio and lecture time. The third phase in studio supports student projects several ways. Before a project is assigned, students learn required skills. Once students are actively working a project, studio time is spent further discussing the project. Most often students need help with their program debugging skills. Students are expected to work on their projects outside of studio time with only the completed projects presented in studio.

One point regarding studio and the projects is to have students face what Jonassen, Strobel, and Lee[7] refer to as Everyday Problem Solving. Studio provides an opportunity for practicing what they refer to as story problems. They further state that to solve workplace problems, students must develop conceptual frameworks they can apply to solve more realistic problems. In my experience, learning the process of solving problems involves deep learning that is performed at the student's own pace. The independent project work that students perform provides opportunity for such deep learning.

Studio Versus Lecture and Laboratory

Despite being instructor led and scheduled separately from the lecture component, there are clear differences between our studio format and lecture format. In studio, students are engaged in hands-on and cooperative learning exercises. An emphasis of studio format is active learning on

the part of students. Given that a goal of studio is active learning, at the end of each studio session, students are required to submit a completed exercise of some kind called a turn-in that serves as proof of their activity. As an instructor the turn-in is a helpful indicator of student progress. I was surprised that in questionnaires, students remark that they like turn-ins. While some students feel that a turn-in is another form of taking attendance, others feel that turn-ins help to foster a low-pressure learning environment.

In a laboratory session, students work fairly independently, alone or in groups with the general goal of completing a project, and later submitting a project report. The direction provided in laboratory is intended to help the students achieve that goal. An issue with introductory courses is that early on in the semester students have not yet acquired the skills and knowledge required to make effective use of the laboratory to act independently. Unless the goal in itself is to teach such skills, this time is essentially wasted. In contrast, studio format provides an effective means to get the students active, even early in the semester. Quite often, the studio session first meets in the first full week of classes.

We believe that completing projects gives students an opportunity for deep learning. Unlike circuits, electronics, or digital logic, it is difficult to organize microprocessor engineering content into projects that students can complete independently in a three hour laboratory session. In teaching an advanced microprocessor course at the Worcester Polytechnic Institute, (ECE4801 Advanced Computer System Design, 1999-2000) it was my experience that so-called laboratory sessions provide a great opportunity to provide student support as they work independently. With this observation in mind, to provide project related content here, this course has two modest projects that students perform independently, outside class or studio, at their own pace. As with laboratory, studio can also provide skills and resources that students need to work independently.

Studio Space

As discussed by Wilson[5] as well as Little and Cardenas[4], the physical space used for studio can have a profound effect on student learning. Our college is small and on a limited budget. However with minor changes, a fairly conventional classroom can be prepared for use with studio. I have learned from experience that a traditional class room, having desks and chairs facing the lecturer with computer monitors facing in the opposite direction provides many opportunities for students to be distracted.

By turning the computers to face the walls, as in Figure 1, the room has an entirely different feel. The classroom now allows for at least three points of focus. In performing hands-on activities and cooperative learning exercises that involve computers, pairs of students use computers spaced out along the walls. During class discussion or mini-lectures, students turn from their computers to pay attention to the instructor. A long table in the center of the room allows student groups to work on non-computer related activities.

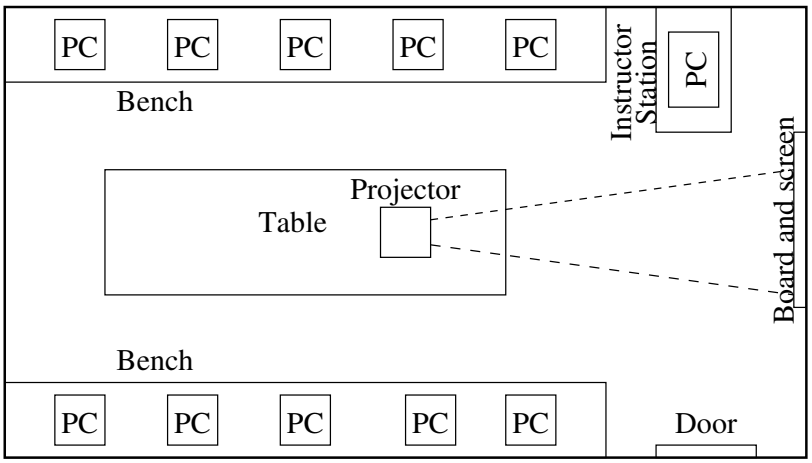

Figure 1: Studio classroom

Having a ceiling mounted projector as well as a screen and marker board makes the classroom friendly to traditional lectures as well. In my personal experience, this new arrangement helps tremendously in teaching in studio format. I agree with Wilson[5] that to some extent the studio format is designed to transfer some responsibility from the faculty to the student. After all, in cooperative learning and hands-on exercises, the focus is on the student, rather than on the presentation of materials to the students. There is an interaction between the students themselves and between the students and the instructor. The instructor as well as the classroom itself serves to facilitate learning.

Assessing Results

Our assessment relies primarily on a questionnaire written for our use of studio format, as well as the exit questionnaire for graduating students. The first exit questionnaire given, following the addition of studio content provided positive results. One question in the exit questionnaire asks students about their ability to analyze, design, and evaluate performance of microprocessor and digital systems. The 2002-2003 year exit survey reports an 80% satisfaction level, up from 60% the previous year. The immediate increase is attributed[6] to the addition of studio content in providing students with more contact and practice time. The following are from the studio questionnaire. Each question is asked on the following five point scale. To avoid a bias in calculating averages, the questions not answered are just discarded.

1	2	3	4	5
Disagree Strongly	Disagree	Not Significant	Agree	Agree Strongly

Questions 1, 3, 4, 5, 7 and 10 ask students for their general impression of our use of studio. In nearly all cases, students see studio content as beneficial in itself, as well as for other aspects of the course. In examining the data, in 2005 class quizzes and the midterm exam were given in studio. Other years had quizzes given during lecture. This seems to have had the most effect in question 4 and question 10. In 2006 only the midterm exam was given during a scheduled studio time, and does not appear to have any noticeable impact.

	2002	2003	2004	2005	2006
1) Overall I see studio content as a good thing	4.38	4.67	4.31	4.54	4.27
3) Studio helps me to better grasp course material	4.38	4.58	4.18	4.14	4.38
4) Studio helps me to better master the software tools	4.43	4.39	4.41	4.07	4.44
5) Studio helps me to master examples discussed in lecture	4.38	4.37	3.94	4.07	4.19
7) Studio helps me to make up for the pace of normal lecture	4.05	4.17	3.29	3.57	3.31
10) Studio helps prepare me for projects that I perform independently	4.47	4.47	4.18	3.75	4.44

While question 7 is positive, it is not clear why it consistently has the lowest score. This may involve the issue of pacing the studio, or it may involve student's perceptions of how studio is different from lecture. In looking at the comments students made, a small number made a comment that they felt that the pace of a two-hour studio is too fast. Others felt that a three hour studio is too long. One student felt that studio involved too much waiting on other students and that the pace was too slow. This suggests that some tension may be present, caused by students with different abilities, working at different speeds. Some tension may be relieved with additional teaching staff to help the instructor support the students.

Several students commented that having low-pressure grading in studio helps to set a relaxed tone, conducive to learning. The studio component of the overall grade is based on turn-ins submitted at the end of each studio period. Despite the effort of producing a turn-in most students feel the turn-ins are a form of attendance checking. All the students appear to be more than happy to produce a printout or writing at the end of each session. It is encouraging to see that the students are sincere and that they take studio seriously with a sense of good humor.

The issue of pacing is related to the issue of class length, which is addressed by questions 8 and 9. In fact, our studio sessions have been varied from 1.5 to 3 hours in length, so question 8 asks for their opinion of a short studio session and question 9 asks for that of a long session. The largest difference is seen for 2006 which had 3 hour studio sessions. Most students disagreed that a three hour session is not useful.

	2002	2003	2004	2005	2006
8) A one hour studio makes good use of my time	4.16	4.40	4.06	3.67	4.19
9) In hind site, a weekly three hour lab would not be useful in ECE332	3.72	3.53	3.41	3.50	2.81

For 2002 to 2005 in question 9, most students feel that a three hour studio session is not useful. Yet in 2006, with three hour studio sessions, students felt just the opposite. A separate question asked students to elaborate on their answer to question 9. The actual question and a few of the comments are next.

Please make a comment, comparing your experience in ECE332 to courses that include significant lab content. You can explain your answer to question 9.

- Studio works well because any longer would be tedious.
- Labs take up too much time, studio is quick & to the point
- Studio was easier than most labs I've had
- The time we spend in studio is more productive than a 3 hour lab
- Less stress, less chaos
- I do not feel necessary to have 3 hours, 2 hours is plenty enough
- A 3 hour lab time would not be very efficient because of the differences in pace that students work at. This makes scheduling tasks more difficult
- I wouldn't mind using more studio time to work on independent project but all in all it was done very well.

In reviewing student feedback and reflecting on my own experience, 1.5 hours is hardly enough time to accomplish a task in studio. Between 2 and 3 hours is ideal. I agree with the students however, that 3 hours is a long session.

Conclusion

The introduction of studio content to this course has changed it from being a bother, to being truly appreciated by students. In expanding this course, studio content was added as an alternative to laboratory content. In particular, studio provides a means early in the semester to get students busy. During our use of studio format, it has evolved to include three noticeable phases, an early phase, a practice phase, and a project support phase for projects that students perform outside of class and studio. We find that studio format helps greatly in teaching introductory microprocessor topics. We are continuing to refine my use of studio format in teaching this course.

Bibliography

1. http://www.hc11.demon.nl/thrsim11/thrsim11.htm
2. Peter Spasov, Microcontroller Technology the 68HC11 and 68HC12, fifth edition, copyright 2004 by Pearson Education, Inc.
3. Andrew Tanenbaum, Structured Computer Organization, fifth edition, copyright 2005 by Prentice Hall.
4. Patrick Little and Mary Cardenas, "Use of Studio Methods in the Introductory Engineering Design Curriculum," Journal of Engineering Education, July 2001, p.309-318.
5. Jack M. Wilson, "Re engineering the Undergraduate Curriculum," chapter 7 in, The Learning Revolution: The Challenge of Information Technology in the Academy, copyright 1997 by Anker Pub Co.
6. Univ. Hartford ECE Dept., Program Self-Study Report, Bachelor of Science Program in Electrical Engineering, submitted to the Engineering Accreditation Commission (EAC) Accreditation Board for Engineering and Technology (ABET), June 2003.
7. David Jonassen, Johannes Strobel, and Chwee Beng Lee, "*Everyday Problem Solving in Engineering: Lessons for Engineering Educators*," ASEE Journal of Engineering Education, Apr. 2006, pp. 139–151,