Active Learning by Lecture and Laboratory Integration in an Emerging Engineering Program

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Abstract – The development of a new Electrical and Computer Engineering program provides an opportunity for designing and implementing an innovative curriculum. In terms of teaching methods, a combination of lecturing and hands-on learning is selected. Studio-style teaching is reported to enhance student learning, compared to the classical lecture and lab formats. However, course organization is different and requires adaptation and innovation in course design, content, and delivery. A studio lab was organized and new equipment was acquired for laboratory stations that include traditional stand-alone instruments as well as sets of computer-based laboratory equipment. The first ECE courses offered at the outset of the new ECE program consist of introductory Electrical Circuits and junior-level Microprocessor Applications. Both courses are developed as prototypes and offered for the first time in studio format. Student reactions and faculty experiences with both the development process and these first course offerings provide valuable feedback for other courses scheduled for the following term, including Signals and Systems and introductory Digital Design, offered in studio-format as well. This article reports the initial experiences with studio teaching for two major core courses in the ECE curriculum, including facilities, equipment, course content, and the design of course material for studio delivery. This experience, aimed at enhancing student learning, may be of interest to other instructors contemplating the use of studio-teaching in their own programs.

Keywords: studio-style instruction, active learning, peer-interaction, new engineering program.

INTRODUCTION

Engineering graduates with the best practical design, analysis, and team effort skills will have the best career opportunities [1]. However, students often find it difficult to connect the theoretical and practical aspects of engineering [2]. Increased motivation and participation in the learning process helps students work harder and learn faster. A proper environment is also needed, so that they can learn both effectively and efficiently [3]. Accordingly, there is a continuous effort in search of more effective content delivery methods in order to achieve the skills needed in engineering. Students should learn to apply what they do know, while being innovative [4]. Projects and laboratories provide hands-on exercises that stimulate curiosity, bring relevance to the theoretical training and provide a practical foundation to engineering skills [5].

Studio-style [1-14] teaching comes as an effective method to address the needs of engineering education. The method, pioneered in the nineties by the Rensselaer Polytechnic Institute [6], has shown effective gains versus the traditional separate lecture and lab instruction [6, 7]. Moreover, most studies show that students enjoy the format and find it more enjoyable and helpful than traditional instruction [8, 7]. While it is agreed that studio-style instruction combines lecturing with hands-on experimenting and cooperative learning, its precise meaning [9] and implementation [3, 10-12] vary.

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Fig. 1 The Science and Engineering Complex : current construction status and planned final appearance.

For instance, while in some cases students could go through both mini-lectures and mini-laboratories in almost every class session [7], others could have the studio format every couple of lectures [12], or in the second part of the course [11, 13].

Studio-style teaching requires a combined laboratory infrastructure with the regular classroom teaching needs. Although this may be perceived as expensive [10], affordable solutions (mobile studio) were implemented lately [7, 14].

A new electrical and computer engineering (ECE) program [15] is being developed at our institution and studio-style instruction is the method of choice. The college provides a strong liberal arts environment and foundation for the engineering program, somewhat similar to the conditions reported in [2]. The ECE program is likely to start in the Fall of 2012, even though ECE courses have been offered in Fall 2011 for students in physics or computer science, who can take them as electives, or to prospective ECE students already present. The full deployment of the program will occur in a new Science and Engineering Complex, currently under construction, as shown in Figure 1, which will be available in Fall of 2013, with classrooms designed for studio-style instruction. Studio-style teaching requires a layout and equipment that facilitate both traditional lecturing and experimental stations with the ability for students to comfortably transition from one activity to the other. Such a layout is illustrated in Figure 2; students can easily rotate their focus and attention from a laboratory bench to a lecture desk. The room is tiered to allow easy visibility for the students towards the instructor and for the instructor to see the stations instrument panels and computer displays.

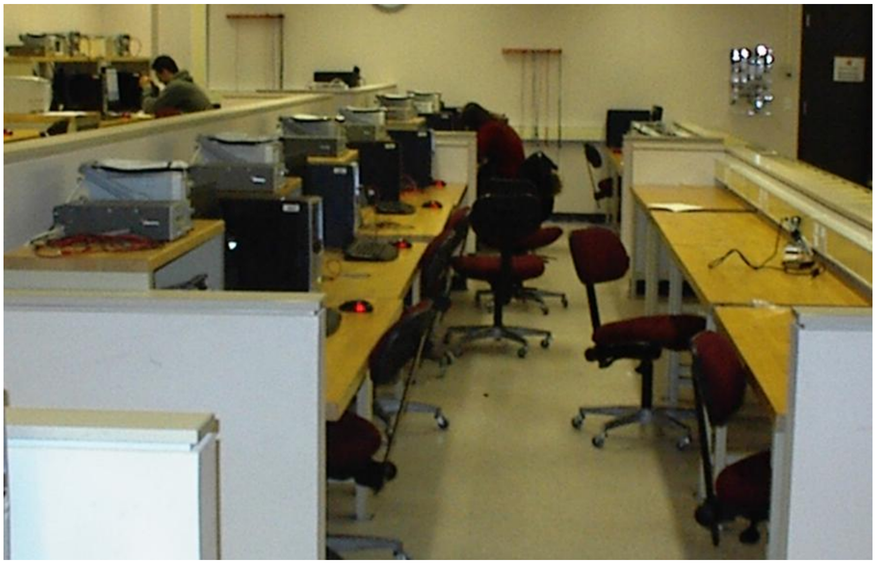

Fig. 2. Studio Lab Layout (Rochester Institute of Technology)

This article presents first experiences with studio-style instruction in the Electrical Circuits course and a junior-level Microprocessor Applications course, two pilot courses that were offered to reveal best practices and directions for improvement for future courses in the ECE program.

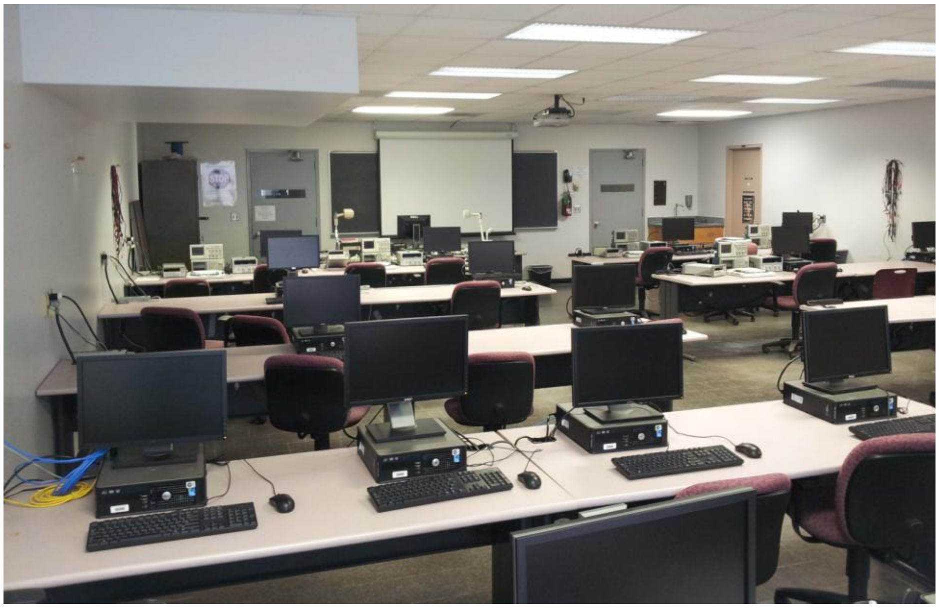

Fig. 3. Current Temporary Studio classroom

Course Structure and Implementation

A. Electrical Circuits

ECE 211 is a 4 credit-hour course in introductory Electrical Circuits co-listed with a physics (PHY362) course whose content overlaps quite significantly. It covers classical topics on resistive circuits, energy-storage elements, control sources, operational amplifiers, power, transformers, DC and AC operation of circuits, measurement and simulation techniques. The class met for 2 hours 3 times each week, very similar to other reports on studio format instruction [3]. The temporary studio classroom, shown on Figure 3, is typically used for computer science courses. Hence, it is fully equipped with computer stations. New equipment was purchased for the first ECE laboratory. Only five ECE lab stations were needed for fall 2011 and they were set up in the two front rows of the room. Each workstation is equipped with stand-alone instruments including dual power supplies, oscilloscopes, digital multimeters, and arbitrary waveform generators. The literature reports that "Mobile studio" virtual platform [7, 14] is a good and cost-effective tool for studio format teaching. Each lab station also includes a computer-based National Instruments™ Elvis II board. Only 5 workstations were setup with additional instruments, as there were 8 students enrolled in the course with two withdrawing during the semester due to illness and other reasons. Although there were enough stations, students were asked to work in groups of two, usually in order to encourage cooperation and peer learning. However, students worked individually on all Multisim simulation activities.

The course was announced to proceed in a studio-format, which created significant interest for the students enrolled. Due to administrative reasons, delivery in studio format actually started after the third week of classes. This is not an uncommon practice, as some instructors plan to have the studio format only during the second part of the course [11], or every couple of lectures [12]. However, due to the announced studio-format instruction, students were impatient and eventually thrilled to use the new equipment. Lecture time and lab time were split in approximately equal time intervals, with a few exceptions. During the first weeks without lab work, the two hours were used for lecture only. This style was favored by some students, but for others following a two-hour lecture was difficult. Once the lab stations were set up the rest of the course except for the last week of classes followed the studio-format instruction. The lecture was focused on the main concepts exemplified on various problems solved in class. Laboratory instructions were uploaded periodically on Angel and students would use the guidelines in class. Normally, one set of lab instructions would be sufficient for a week or more. Concepts would be presented in the lecture and students could actually work and see some of them in lab applications. Although comprehensive details on the procedure to follow were not given in the laboratory instructions, the instructor was available for help and questions at all times. Part of the lab work was inspired from another lab course [16] but additional adjustments were needed to reflect the new equipment available. Moreover, all lab work was in synchronism with the lectures, giving more relevance to the theoretical concepts learned.

Some of the labs required completion in class, while others asked for a formal report. The lab component had a 20% weight in the calculation of the final course grade. Additional lab stations were set up and made available to students outside class time. This is a transitional phase until the new building and dedicated studio classrooms are going to be available in the Fall of 2013.

B. Microprocessor Applications

Teaching students how to design and implement embedded systems requires providing them with knowledge and practical training on a variety of interrelated subjects in hardware, software, and firmware. The Embedded Systems course is offered at the junior level and its objective is to provide students with a hands-on introduction to microprocessors, microcontrollers, their organization, their programming, and their applications in embedded control systems.

Student preparation consists of a course in digital design and a concurrent course in electronics. Both the pre-requisite course in digital design and the co-requisite course in electronics will be offered in studio format as well. This helps ensure that knowledge of fundamental concepts in digital design and use of laboratory methods and instrumentation are already acquired.

Teaching embedded systems in studio style greatly enhances student learning as each session covers material that is immediately implemented, verified, and applied. Doing this requires augmenting the lab stations discussed above with additional equipment specific to the embedded systems course content. Firstly, a microprocessor or microcontroller educational board is needed. In the case of the course discussed in this article, the processor chosen to support course content and embedded systems experiments is the Motorola 68HC11 microcontroller [17]. A most important characteristic of this platform is its widespread popularity as an educational device, the availability of several low-cost educational boards, and the large body of supporting software, development tools, documentation, educational materials, and applications found on the internet at either very low cost or completely free of charge. Three popular HC11-based educational boards -- the Wytec Fox11 EVBU [18], the Axiom CME11E9 EVBU [19], and the Handy Board [20] -- are pictured in Figure 4.

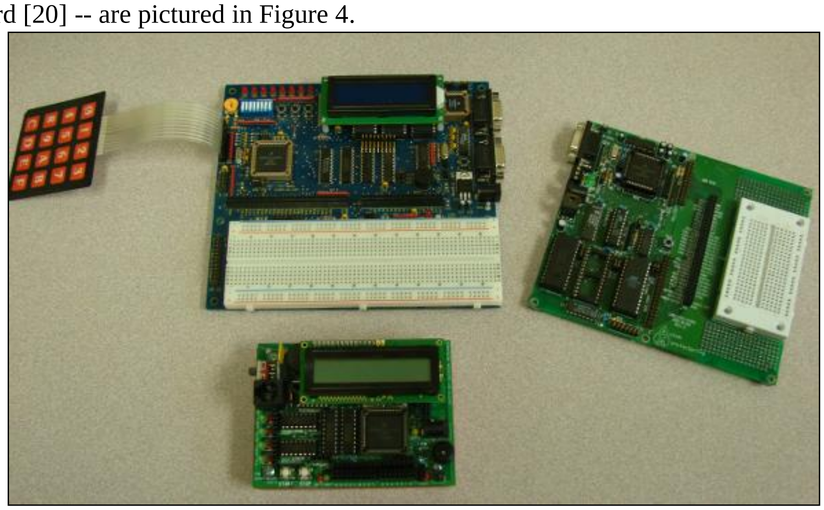

Figure 4. Microcontroller boards: Fox11, Axiom 11, and Handy Board

ASSESSMENT

The ECE 211 course was much enjoyed by the students, according to formal student feedback as well as from informal discussions. An exit survey showed in Table 1 was answered by five students after the course ended. The results are plotted in Fig. 5.

Please rate from 1 to 10 (10 the highest level).

Table 1. Questionnaire used for student feedback.

Q1	Was the lab work relevant to course content?
Q2	Do you think the integration of lecture and lab was good?
Q3	Do you think the support from the instructor was adequate?
Q4	Was the lab work conducive to meaningful learning?
Q5	To what extent did the course meet your expectations?
Q6	Overall, was this course conducive to learning?
Q7	To what extent did the lab increase your interest in the course?

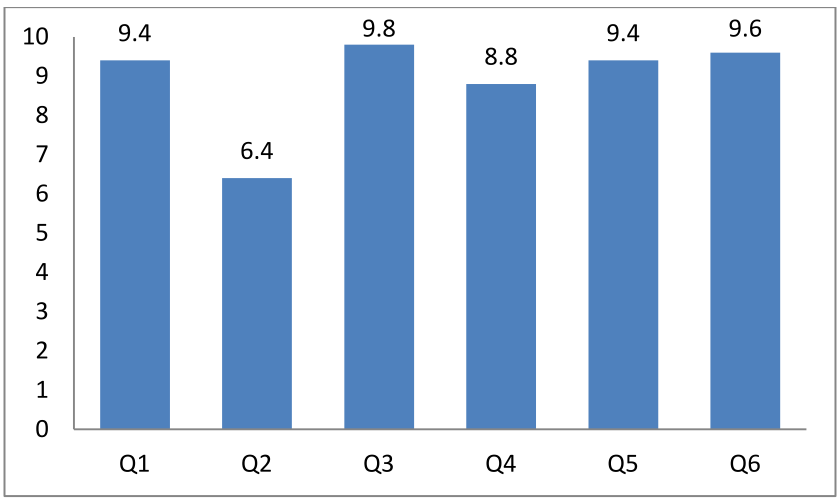

Fig. 5 Plot of the average feedback results corresponding to questions Q1 to Q6 in Table 1.

It is apparent that lab work was well matched to course content, both from the students' point of view as well as from the instructor's perspective (Q1). Students did feel that they were helped adequately during the lab (Q3) and the course met their expectations (Q5). Moreover, the course was certainly perceived as conducive to learning (Q5). The lab appears to be conducive to learning, but the slightly lower score average may be related to the less detailed instructions in lab work descriptions, which were sometimes limited on purpose to allow for more independent work and discovery.

Question Q2, although positive in meaning, shows a rather poor student perception of the completeness of lecture and lab integration process. They liked the course content, presentation and their learning achievements in the course, but are aware of the additional work that can be done in order to blend the course components well. The course was a pilot, and the classroom workstations were set up during the semester. The classroom and equipment were essentially not accessible outside class time, due to the full use of the classroom mainly for computer science courses. Therefore, additional workstations were set up in a different room allocated for such purpose and accessible. Such factors presented inherent difficulties, which the students perceived. In addition, most felt that more lab time would be beneficial. These are certainly some directions we will work on for further improvement of the course.

The average for question Q7 (not plotted in Fig. 5) was 60%, which again shows the significant impact of the lab component on the lecture part and also points to the perceived interdependence (and integration) of the two.

The main topics for laboratory work are listed in Table 2. The average values are plotted in Fig. 6. In the exit survey, students were also asked to rate the laboratories from 1 to 10 according to their preference. It is apparent that the most liked lab work was on Op-amps (L4) followed by RC Circuits (L6).

L1	Ohms law, resistive networks
L2	Superposition
L3	Thevenin, Power Transfer
L4	Op-amps
L5	Differentiator and Integrator Circuits
L6	RC circuits
L7	AC / RLC circuits
L8	RLC resonance

Table 2. List of the main laboratory work.

The Differentiator and Integrator Circuits (L5) had the lowest rating (8.6/10) which may be related to the fact that it required more independent work, and the formal report requests were more comprehensive than for other reports. Nevertheless, it should be noted that all the ratings are above 8.5/10, with an average for all labs of 9.2/10, which does show that students enjoyed the lab work. This is much in agreement with the instructor's direct observations.

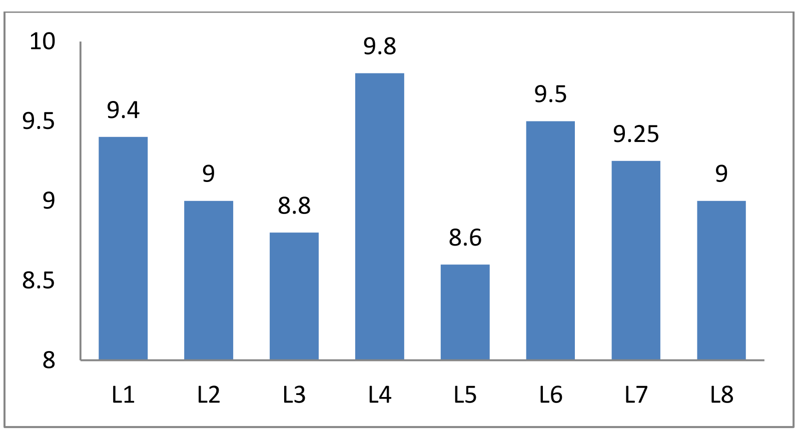

Fig. 6 Student ratings of lab work on a scale from 1 to 10.

It may be difficult to organize engineering content into projects that students can complete independently within the time allocated [9] for the lab during studio-style instruction. We thought we can bypass this issue by allowing the lab to extend onto multiple sessions. Students were informed that the lab work may overflow from one session to the other and they would normally have a few sessions to complete the work. Nevertheless, it appeared from their feedback that they would still strive to finish within the same session, although not always possible. Students felt that they needed more lab time. The observation is in agreement with what was noticed by others [7]: projects should be selected carefully as often the students show a lot of enthusiasm at the beginning but decrease their enthusiasm once they realize that some projects may take too much time. Students enjoyed the Circuits course, but they felt that a longer time for the lab work could be more beneficial, although they had available workstations to work on and finish the lab at their leisure. Here are some sample comments:

** "Some labs were too long due to the setup time."*

** "We did not have enough time to finish labs…"*

** "More lab time would be good."*

Some instructors were concerned that if the entire course were to adopt studio format, there may be a tendency for the lecture component to be dominant [9]. Although this overflow into the lab work has rarely happened, some students would have liked to actually have longer lecture time and cover more material in the course. According to student comments:

"*Being able to learn something in the lecture and then do it in the lab all in the same day was a great aspect of this course. However, I feel that spending less time on labs and more time covering material would be helpful*."

In the authors' opinion this may be an induced misperception by their first experience with the studio instruction, as in the past the format based on separate labs and lectures enabled us to cover the same or less amount of material.

Additional difficulties were due to the class meeting at 8 a.m., which might have been restrictive. Some students had no problem with the course time but others agreed that the best class time would be in the afternoon.

Students showed that they greatly enjoyed the lab work, which also stimulated their interest for the lecture. Here are some comments:

** This class is very interesting and very enjoyable.*

** I enjoyed learning about various ways to solve different circuits. I enjoyed all of the math involved.*

** I liked using all of the new equipment.*

** The Elvis board made things simpler but not as accurate.*

** I like all of the different methods we have learned to analyze circuits.*

** I am really enjoying the course.*

** I find the material very interesting.*

** The course is very enjoyable and I really like the instructor.*

** I really enjoyed all of the labs but I definitely liked the ones using the Elvis board the most*

CONCLUSIONS

The studio-format instruction favors peer-interaction and active learning. We have presented our experience in two pilot courses, with positive outcomes and new directions for improvements. The students enjoyed the pilot courses taught in studio-format. It must be noted that course content requires different course delivery format in terms of the relative mix and integration of lectures and labs. It is desirable to provide sufficient flexibility for instructors to tailor material delivery in each course for better student learning. The Electrical Circuit and Embedded Systems courses discussed in this article provided useful feedback for actual course delivery in the future ECE program. Studio delivery requires a particular classroom layout and organization, laboratory equipment, and teaching methods that include active learning. This can only be accomplished by careful selection of experimental topics that emphasize and implement the lecture concepts very closely. However, in addition to experiments conducted under direct instructor supervision, sufficient experimentation to be conducted by students themselves must also be incorporated to teach students self-reliance and experiment design.

The current pilot implementation of the studio-format instruction comes in a transitional environment, which is likely reflected in the students' perception of lab-course integration. Laboratory instructions will be further detailed in the next versions and the studio-format instruction will be generalized to all lectures. The present experience has led us to consider reducing lecture time in favor of laboratory work for most sessions. Accordingly, labs will be extended in order to account for the change. The lab work will be adjusted so that it can be completed in a single session, whenever possible. In addition, scheduling class time at 8 a.m. will be avoided in the future. Conclusions from our experience will also helped with design the Signals and Systems and the Digital Design courses taught in the Spring of 2012. Class size for the courses analyzed here was small, hence the conclusions cannot be statistically relevant. Nevertheless, they point in certain directions worth considering by others as well.

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