TEACHING CIRCUIT ANALYSIS IN THE STUDIO FORMAT: A COMPARISON WITH CONVENTIONAL INSTRUCTION

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Abstract
This paper describes an instructional experiment conducted at Rensselaer Polytechnic Institute in the spring of 1997. The introductory course on circuit analysis was taught in two different modes:

1. A conventional large-lecture version with separate problem and laboratory sections,
2. An experimental studio version with integrated activities.

The director and coverage of both courses was the same, and students in both versions took the same exams.
Exam results indicate that the studio version is at least as effective, if not more so, from the viewpoint of cognitive-domain learning. More significantly, surveys of student attitudes revealed that the studio format substantially improved student morale, despite the requirement for more preparation and participation on their part. Thus, since the instructional costs were about the same for both versions, the studio format appears to be superior.

Introduction

For several years, Rensselaer Polytechnic Institute has been pioneering the use of the studio instructional format [1-3]. Stimulated by successes in the sciences, the Department of Electrical, Computer, and Systems Engineering completed a studio classroom for its introductory courses in circuits and electronics [4] in the fall of 1996. An experimental studio version of the course Circuit Analysis was offered in the spring of 1997, along with a conventional lecture version. The two versions covered the same material, and the students did the same problems, experiments, computer projects, and exams.
This paper reports on student performance and attitudes in both versions. A comparison of the cognitive and affective results supports the assumed superiority of the studio version.

The Courses

Both courses covered basic circuit analysis, simulation, and measurements, and both instructional modes emphasized active learning and student teamwork. To ensure consistency, Prof. Carlson was the director for both versions, prepared all the problems and exams, and led about two-thirds of the class sessions. Professors Jennings and Schoch led about one-third of the class sessions for the studio and lecture versions, respectively, and both of them had previously worked with Prof. Carlson in the lecture course. One graduate teaching assistant also participated in both courses, but additional assistants were assigned separately.
Students in both courses took the same two mid-term exams and final exam, and all exams included a take-home portion that students were encouraged to work on with a partner. Students were also encouraged to do the homework and in-class problems in teams of two. Salient features of the two course versions are itemized below.

Lecture Course

This version had an enrollment of 55 students. It met three times per week for 50-minute lectures, which regularly included interactive examples and/or pencil-and-paper exercises to be done by the students. Additionally, once per week there were 110-minute problem sessions in smaller sections, during which students worked on problems with help available from the teaching assistants. Out-of-class assignments consisted of reading, weekly homework sets, and four computer simulation projects.
Most students in the lecture course also took the circuits laboratory course, which is required for those majoring in electrical or computer engineering. The 50-minute lab lectures alternated weeks with 150-minute lab sessions.

Studio Course

This experimental version had an enrollment of 28 students, determined by scheduling rather than assignment or volunteering. The class met three times per week for 110-minute sessions, and homework assignments were typically due twice per week. The distinctive feature of the studio course was the integration of learning activities, together with the smaller group in the special classroom.
The studio classroom is equipped with 20 work stations consisting of laboratory equipment and networked computers. Besides enforcing student work in teams of two, this arrangement allows lab experiments, computer simulations, and computer analyses to be done directly in class in the context of the topics being considered, with help immediately available from the instructor or teaching assistants. Additionally, the instructor may use a projection system to show computer results for class discussion.
A typical studio class period incorporated several of the following instructional components:

- Brief mini-lectures
- Class discussions
- Pencil-and-paper exercises and problems

- Laboratory experiments
- Computer simulations
- Computer analyses

The mini-lectures were brief to provide time for other classroom activities. Thus, in contrast to the lecture version, the studio students were expected to do the assigned reading and preparation problems in advance of the class.

Results

The cognitive-domain performance of students in both courses was assessed by comparing their total exam scores. To make the comparison as equitable as possible, one studio student who had previously taken the lecture course was removed from the study, and a cohort of students in the lecture version was identified.

The student demographics given in Table I indicate that the two groups were well matched academically. Nonetheless, as shown in Table II, students in the studio course on average performed better on the three exams than the students in the lecture cohort. Note, in particular, that the median score of the studio students was more than five percent higher -- roughly equivalent to half a letter grade.

Table I -- Student Demographics

	Studio Course	Lecture Cohort
Number of students	27	27
Non majors	1	2
Females	5	5
Caucasian	13	14
Black	2	2
Asian and others	12	11
Average QPA	3.179 ± 0.530	3.164 ± 0.532

Table II - Total Percentage Exam Scores

	Studio Course	Lecture Cohort
Average	77.01	75.81
Standard deviation	10.59	10.80
Median	79.68	74.29

Since the two groups were apparently comparable, and since the preparation was the same for both, the studio format itself led to the improved performance. At the very least, the studio format appears to be as effective in the cognitive domain as the more conventional format. But more significant differences emerged in the affective domain, judging from surveys of student attitudes and perceptions.

Table III lists selected average responses from the survey administered to all engineering courses. The "bottom line" here is the overall course rating (statement 16), which was 3.6 on a 4.0 scale for the studio course, as compared with 3.0 for the lecture course. Increased student satisfaction with the studio format is also reflected in the responses to statements 11, 13, and 14.

Furthermore, the studio course received higher positive responses than the lecture course on all aspects of the survey. Of particular interest is the comparison of responses to statements 4, 5, 6, and 10. Since the assignments, exams, etc., were identical for both courses, the studio format again seemed to be more satisfactory from the student viewpoint.

Finally, a special survey was administered to students in the studio course alone for evaluation purposes. Selected results given in Table IV reveal the following points:

- The studio format promoted class attendance. (Indeed, attendance remained above 90% throughout the term, whereas it dropped appreciably in the lecture course.)
- Students appreciated the individualized attention in class and felt less need for extra help outside of the classroom.
- Students did the outside work necessary for the studio class, and felt that they benefited from the experience.
- Students felt that they learned more from the studio format and preferred it to a conventional format.

The higher student rating for the studio course evidently reflects these points.

Conclusions

Based on the results presented here, we conclude that the studio format is clearly superior to a more conventional format relative to student attitudes and at least as effective relative to cognitive-domain learning. As a bonus, the studio format appears to help students learn to learn -- a skill they will need throughout their professional lives. Furthermore, the instructors have found that teaching in the studio environment is a more pleasurable and rewarding experience than lecturing to a larger class. For these reasons, we intend to further develop the studio format and use it exclusively for our introductory courses in circuits and electronics.

Although the studio format usually involves several sections, compared to a single lecture course, the actual delivery costs are about the same, and often lower when viewed on a curriculum-wide basis. For example, when Circuit Analysis was taught in the traditional mode with total enrollment ranging from about 85-100, it was typical to assign two faculty to the course. (Rensselaer faculty are normally expected to teach at least two courses each term unless otherwise engaged in research or administration. One faculty member would spend about 50% of his time on this course and the second about 25%.) In the Studio mode, this enrollment necessitates three sections since the capacity of our Circuits/Electronics Studio is 40. The same two faculty are now assigned; one to handle two sections for 50% of his load and the other to handle one section for 25%. The actual hours spent in class by faculty has increased in the studio mode, but there has been a corresponding reduction in the hours spent by faculty for extra help. The total load on faculty is about constant.

The traditional mode also typically required the use of 40 hours per week of teaching assistants to help with grading, problem sessions and laboratory assignments. We now use the same 40 hours per week to provide assistance in the three studio sections, although it is typical to make more use of seniors rather than graduate students (since a faculty member is always in the studio during class time), leading to an actual small reduction in total personnel costs.

One significant cost saving of the studio version is the possible elimination of laboratories, which are very expensive to offer and maintain. We are actually eliminating a traditional required laboratory course from the curriculum because of the conversion to the studio format of courses in circuit analysis, analog electronics and digital electronics. The 50% of a faculty member and 60 hours per week of teaching assistants previously assigned to this course are now available to help handle the studio sections. In addition, the equipment in the old laboratory is now used in the studio facilities.

To be sure, the studio format does involve some additional costs, primarily for the studio facility itself and for course development. However, these costs can be amortized over several courses and several years. And if the studio format significantly improves both student and faculty morale, then the costs are certainly worthwhile!

References

1. Wilson, J., "The CUPLE Physics Studio," The Physics Teacher, 32, 518, 1994.
2. Roy, H., "The Studio Genetics and Evolution Course," published via the World-Wide Web at http://www.rpi.edu/dept/bio/info/Biosimlab/genetics.html, 1994.
3. Ecker, J., *Studio Calculus*, Harper-Collins, New York, 1996.
4. Maby, E., et al, "A Studio Format for Innovative Pedagogy in Circuits and Electronics," Frontiers in Education Conference, 1997.

Table III - School of Engineering Course Survey

Respondents: 25 in the studio course, 34 in the lecture course
Response scale: 4 = strongly agree; 3 = agree; 2 = disagree; 1 = strongly disagree
Course rating scale: 4 = one of the best; 3 = above average; 2 = average; 1 = below average, 0 = one of the worst

Statement	Studio	Lecture
4. The written assignments aided the learning process.	3.7 ± 0.5	3.4 ±0.7
5. The level of difficulty is reasonable.	3.3 ± 0.7	3.1 ± 0.6
6. The amount of work required is reasonable.	3.3 ± 0.6	2.9 ± 0.8
10. The tests, quizzes, etc., are learning experiences.	3.4 ± 1.0	2.9 ± 0.8
11. The course format is appropriate to the subject.	3.6 ± 0.7	3.1 ± 0.8
13. The course encourages students to think for themselves.	3.6 ± 0.6	3.2 ± 0.8
14. The course increased knowledge/skills in the subject.	3.8 ± 0.4	3.4 ± 0.7
16. Rate the overall quality of the course.	3.6 ± 0.7	3.0 ± 0.7

Table IV - Studio Course Survey

Respondents: 26
Response scale: 4 = strongly agree, 3 = agree, 2.5 = neutral, 2 = disagree, 1 = strongly disagree

Statement	**Mean ± SDev**
1. I attended most of the studio class sessions.	3.9 ± 0.3
3. I appreciated having a staff member nearby in the studio to help me when I needed it.	3.8 ± 0.4
5. I sought out-of-class help for this course more than I usually do.	2.4 ± 0.8
6. I liked having the experiments and computer projects integrated with other studio activities.	3.5 ± 0.6
8. I did most of the out-of-class work with another student.	3.1 ± 0.6
10. I did most of preparation work on time.	3.1 ± 0.5
18. The studio format helped me learn how to learn.	3.4 ± 0.6
19. I think I learned more from the studio course than I would have from a conventional format.	3.6 ± 0.6
20. The studio format felt more “friendly” than a conventional format.	3.8 ± 0.5
21. I enjoyed the studio course format more than a conventional course.	3.8 ± 0.5