AC 2007-943: ACTIVE LEARNING USING GUIDED PROJECTS IN AN UPPER YEAR ECE COURSE

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Active Learning using Guided Projects in an Upper Year ECE Course

Abstract

A fourth year microwave and RF circuits course was designed to follow a guided project format, where class discussion and in-class computer design work contribute to the completion of a final team design project. The class was held in a teaching studio, and half of the three class hours per week were used to allow students to work on computer simulations and design of microwave circuits. Brief multiple choice quizzes at the start of most class sessions encouraged students to complete class readings from the course wiki, allowing in-class time to be used for higher-level discussion and teamwork. A final web-based course survey indicated that over 85% of the students felt that the use of the studio, software, and class discussion were valuable, and were preferable to lectures. Instructor and teaching assistants found the students to have a greater grasp of the technical language, and a much better appreciation of the practical aspects of circuit design. This paper presents the evolution of this course, the outcomes of this format, and three years of student surveys.

Introduction

Education research and classroom surveys over the past 20 years have made it clear that the manner in which a program is delivered plays a very important role in determining the kinds of skills students develop. Engaging teaching practices are critical to student development, and show significant improvements over traditional lecture styles in terms of academic achievement, faculty-student relations, and student attitudes towards their studies.[1] Retention of material presented in lecture format exclusively is known to be lower than when supplemented by active techniques.[2] Active techniques and cooperative learning can not only improve retention, but also develop communication and teamwork skills, contribute to real-world engineering skills, and expose students to broader societal and economic issues[3]. Project based learning is particularly suitable for upper year engineering courses, though used most commonly in capstone design courses.[4]

This paper presents the redesign of a fourth year elective course on microwave and RF circuits and systems. The course was developed with the objectives of: (a) teaching "applied science" theory in the context of engineering application, (b) incorporating professional skills, like teamwork, design, and communication into the course, and (c) structuring class time to keep students active and involved through the incorporation of a course length project.

For the past three years a final web-based course survey was conducted after the end of term to assess student opinions about the course format and their learning. Some of the student comments will be included throughout this paper, though the majority will be discussed at the end.

Course Background

Microwave and RF Circuits and Systems is a fourth year elective course offered over 12 weeks from September to December in the Electrical Engineering program at Queen's University, a mid-size research-intensive university in Kingston, Canada. Prior to 2003, the course was implemented as a standard lecture course, with three one-hour lectures per week. In 2003 a major design project was added to the course. In 2004 the course was modified to use a studio format[5], where roughly one half of each class was used for a lecture, and the remaining half used to complete computer assignments that reinforced lecture topics. The in-class assignments used an industry-standard microwave circuit design tool, and allowed students to simulate circuit behavior. The software also allowed students to "measure", through simulation, the behavior of microwave devices as they were discussed in class. In this way it served as a low-cost, though admittedly less desirable, substitute for dozens of very expensive dedicated microwave stations that could be used by all students simultaneously. The in-class work allowed the instructor and teaching assistant to circulate and assess student understanding in-class, and to correct common misunderstandings.[6]

The course evolved again in 2006 to use a guided project format, where most class discussions and in-class work contributed to a the final course project, rather than stand-alone assignments. The course material was restructured from a linear presentation of topics to the just-in-time delivery of material as needed for the design of a project involving amplifier design. Students were asked to form pairs, and each pair was assigned the responsibility to design a receiver front end at a particular frequency that corresponded to a particular wireless standard, e.g. GPS, IEEE 802.11b, and PCS. Most of the course work involved the design of these front ends, particularly the low noise amplifier (LNA). Students were given the option of laying out and fabricating their designs for extra credit. The course final grade included the in-class work, quizzes, design reports, and a final exam.

Classroom facilities

In 2004 Queen's University opened its Integrated Learning Centre (ILC), an innovative facility with no traditional classrooms that includes 42 student group rooms, a Design Studio, and a Teaching Studio. The Teaching Studio, used for this course, is an oval room with 35 workstations, and seats 76 students. It includes a "smart" white-board, a video distribution system from the instructor's computer to student monitors, and an electronic voting system. The room lighting and color scheme was chosen to provide a comfortable work environment. Students sit in two concentric rings, and face either the center of the room or the edge, as shown in Figure 1. When facing the center they see the instructor, and a flat-screen monitor; they may turn around to face a shared workstation. Students can easily see all other students, the instructor, and the teaching assistant, aside from the few students seated immediately in front or behind them. This greatly improves communication between students, and with the instructor, as will be discussed later in the survey results.

Typical class session

The class sessions were structured to allow for reinforcement of important class concepts, to provide multiple methods of learning for various student learning styles, and to allow immediate assessment of student understanding. A typical class session includes a very short student presentation, a brief multiple choice test, instructor-led discussion and student activity. An idealized class time-line is shown in Figure 2.

Figure 1: Teaching Studio used for the course.

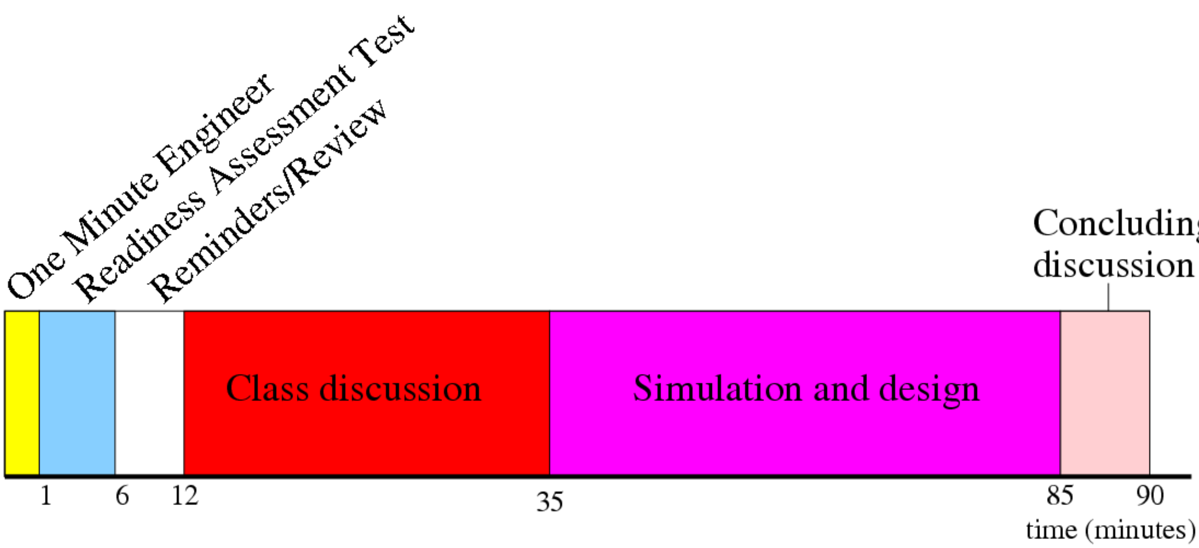


Figure 2: Typical class session time-line.

At the beginning of the semester students were asked to place a name-tag in front of them to allow the course instructor and teaching assistant to learn their names. This provided the opportunity for the instructor to ask students directly. On the final course survey at the end of the semester, several students commented that the prospect of being called upon to contribute was a significant motivating factor.

One of the objectives of the course was to place microwave and RF circuits in the greater context of engineering and society. Toward this end, all students were required to present a very brief talk on any engineering topic of their choice once in the semester. This was entitled the One-Minute Engineer, and was adapted from an excellent session by the same name used at Northeastern University and Pennsylvania State University.[7] The student instructions were as follows:

Each class one pair of students will have 60 seconds to present on an engineering topic of interest to them; this could be on engineering in everyday life (e.g. the materials used in composite bike frames, or GoreTex laminate), recent news (e.g. a new wireless standard), or a journal article. Remember that you only have 60 seconds, so the presentation must be to the point. No computer presentations are allowed, but you are encouraged to bring in props to highlight your topic!

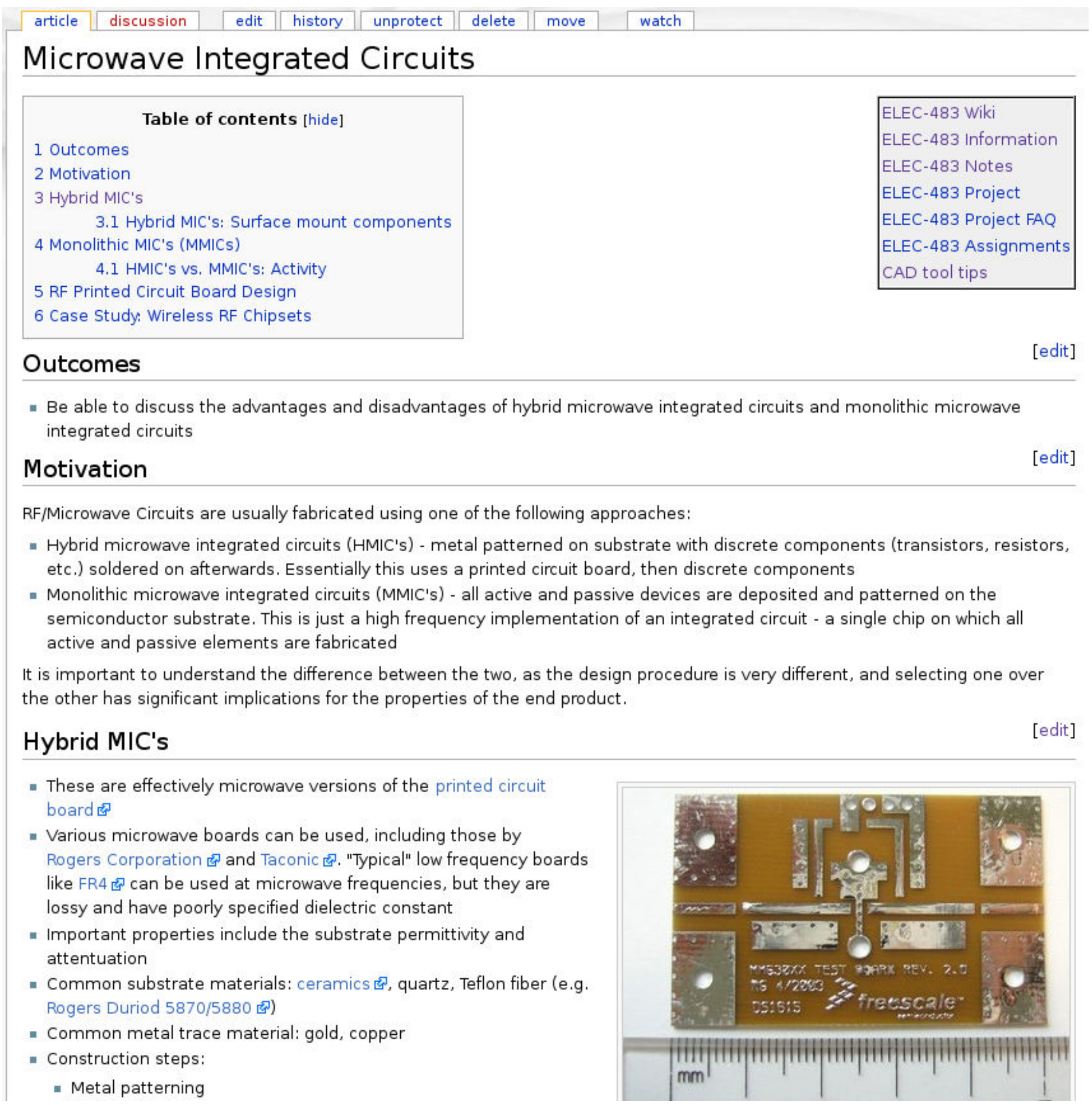
Students presented on a wide range of topics, including nano-materials, video surveillance, integrated circuits, and were generally quite attentive during the sessions.

One concern that may arise when an instructor considers introducing active techniques (e.g. group work, class discussion, projects, etc.) into a lecture course is the reduction in time available to cover the course "content", as spelled out in a syllabus. A persuasive argument can be made for the value of a deep understanding of a few fundamentals compared to a surface exposure to a wide range of topics[8], and it is possible to adjust the course to efficiently use in-class time to develop deeper understanding without significantly sacrificing breadth. One technique is to structure the course grading to encourage students to complete the assigned readings from a course textbook or notes, allowing them to pick up the lower-level concepts outside of class. In this course, readings from the course notes on a wiki, which will be discussed shortly, were assigned before each class. The first five minutes of most classes were used for a quiz with four multiple-choice questions based exclusively on concepts from the class readings. Several students commented throughout the course that this encouraged them to keep up with the course, and allowed them to contribute to in-class discussion more than they otherwise would have. Overall students were able to discuss topics and answer questions in class far better than in previous years, and less time was spent lecturing on the fundamentals.

The course notes were posted in a wiki, which is a website whose content can be edited by many users; part of one such page is shown in Figure 3. Ideally this allows students to contribute to course material, add new topics, and correct errors. The course wiki served as a set of online notes, and was used as a reference for the in-class discussion. Hyperlinks to external websites, e.g. manufacturer data sheets and Wikipedia, made it possible for students to find background information on topics that interested them. Unfortunately outside users defaced some of the pages early in the semester, so the editing feature was disabled for everyone aside from the course instructor until an authentication system could be implemented.

Wikis often have a “talk” page for each web page, that allows users to post comments on the content of the page. One student suggested that these talk pages be used to facilitate discussion and allow students to post questions that could be answered by other students. This is an idea that will be implemented for the next year.

The class discussion was used to summarize the concepts covered in the assigned readings, discuss practical applications, and address questions. Occasionally the instructor found himself reverting to verbose lecture mode, and putting students to sleep, despite good intentions! The built in video-distribution system was used to display the contents of the wiki, and highlight diagrams and plots that were used in the discussion.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Microwave Integrated Circuits

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Outcomes [edit]

- Be able to discuss the advantages and disadvantages of hybrid microwave integrated circuits and monolithic microwave integrated circuits

Motivation [edit]

RF/Microwave Circuits are usually fabricated using one of the following approaches:

- Hybrid microwave integrated circuits (HMIC's) - metal patterned on substrate with discrete components (transistors, resistors, etc.) soldered on afterwards. Essentially this uses a printed circuit board, then discrete components
- Monolithic microwave integrated circuits (MMIC's) - all active and passive devices are deposited and patterned on the semiconductor substrate. This is just a high frequency implementation of an integrated circuit - a single chip on which all active and passive elements are fabricated

It is important to understand the difference between the two, as the design procedure is very different, and selecting one over the other has significant implications for the properties of the end product.

Hybrid MIC's [edit]

- These are effectively microwave versions of the printed circuit board
- Various microwave boards can be used, including those by Rogers Corporation and Taconic. "Typical" low frequency boards like FR4 can be used at microwave frequencies, but they are lossy and have poorly specified dielectric constant
- Important properties include the substrate permittivity and attentuation
- Common substrate materials: ceramics, quartz, Teflon fiber (e.g. Rogers Duriod 5870/5880)
- Common metal trace material: gold, copper
- Construction steps:
  - Metal patterning

Figure 3: Course wiki used for readings and background information.

In-class assignments

Approximately half of the class time was used to allow students to do simulation and design work on the computers. The design suite Advanced Design System (ADS) from Agilent, an industry standard package used for microwave circuit design, was used extensively. Several tutorial-type assignments were provided at the beginning of the semester to familiarize students with the package, and to introduce basic microwave topics. As the semester progressed, the class topics contributed to the project design, and the assignments required students to work on their design projects. For example, after discussing microwave transistor stability students would be instructed to examine the stability of their transistor at their design frequency, and after discussing microwave matching networks they were asked to design matching networks for their amplifiers. The course instructor and teaching assistant circulated around the class asking questions and helping the students improve their understanding and design skills.

The simulations used packaged transistor and passive component models made available by manufacturers. This exposed students to data-sheets, and exposed students to practical "non-ideal" behavior of microwave components. In the middle of term, students met with the course instructor or teaching assistant to review their design, and receive formal feedback on their progress. At the end of term, they were asked to compare their designs to commercially available products.

Course Survey results

A simple five-question online survey was sent to all enrolled students at the end of the course in the academic years from 2003 to 2006. It should be noted that almost all other courses in the students' program use a traditional lecture style, so some of the questions asked the students to compare the styles. The students were asked the questions below; the possible responses are shown in **bold**. An open text box was also provided below each question to allow students to provide more detailed comments.

1. Do you feel that holding the course in the Teaching Studio, and using the studio format, helped or hindered your learning compared to the traditional lecture format? **(Helped very much/Helped somewhat/Little difference/Hindered)**
2. Did the layout of the Teaching Studio help or hinder you in communicating with the instructor and other students compared to a traditional classroom? **(Helped very much /Helped somewhat/Little difference/Hindered)**
3. Do you feel that the use of ADS helped or hindered your understanding of microwave circuit design? **(Helped very much/Helped somewhat/Little difference/Hindered)**
4. Do you feel that your learning would have been helped by more "lecturing", or by more in-class assignments? **(Helped by more lecturing/Helped by more in-class assignments/Little difference)**
5. Do you feel that your learning was helped or hindered by the final project? **(Helped very much/Helped somewhat/Little difference/Hindered)**

Table 1 below details the evaluation responses for the past three academic years. It should be noted that the drop in course enrollment is roughly proportional to the drop in overall program enrollment from 2004 to 2006.

	2004	2005	2006
Course enrollment	70	48	33
Respondents	20	25	14
Percentage Response	29%	52%	42%

Table 1: Course survey participation

The qualitative and quantitative feedback from each question will be discussed below.

Questions 1 and 2: Use of the Teaching Studio as an Aid for Learning and Communication

The response to the first two questions was consistent over the three survey years at greater than 85% in favour (helped learning/communication very much or somewhat), and 100% in favour by 2006, as shown in Figures 4 and 5. The student feedback stressed the proximity to the instructor and other students as being conducive to improved peer-to-peer and student-to-instructor interaction. Students commented that it was easier to ask questions because of a lack of distraction due to the studio layout. The free circulation of the instructor and the teaching assistant (TA) during the in-class exercise also increased interaction and allowed for identification and resolution of questions quickly and effectively.

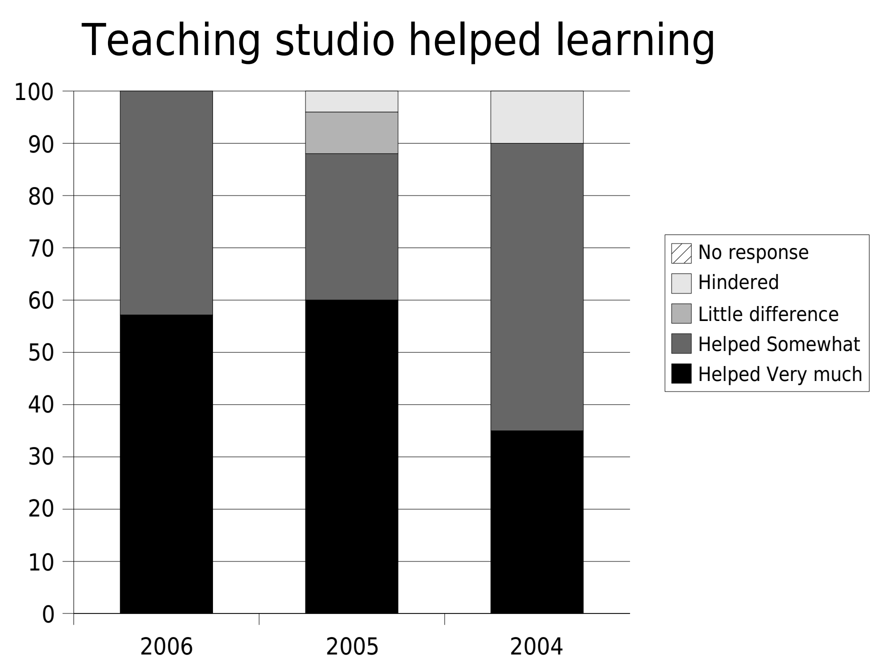

Figure 4: Percentage response to question 1

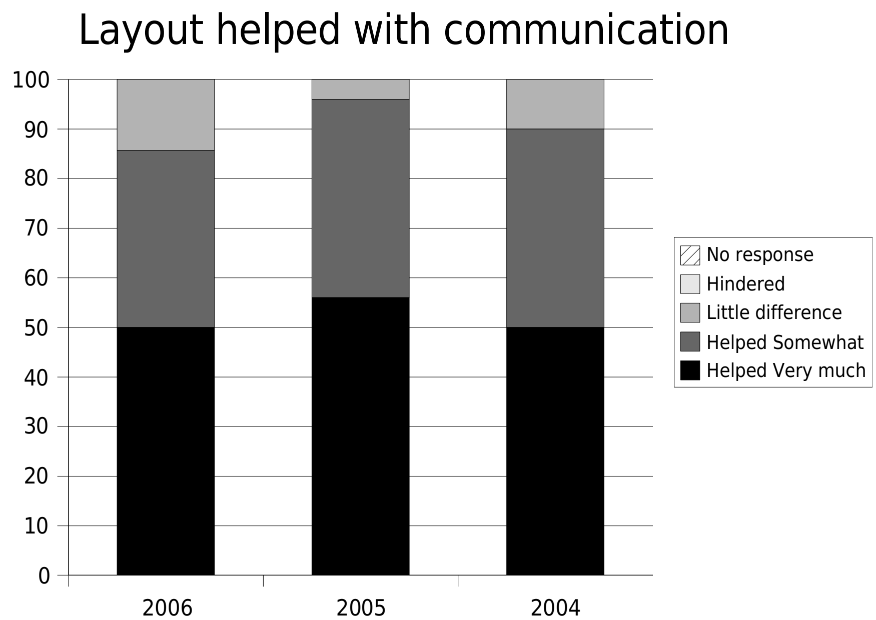

Figure 5: Percentage response to question 2

Question 3: Effectiveness of Simulation Software as a Learning Aid

The student response to the use of the computer simulation tool ADS shows a steady overall increase from 80% favourable (helped very much or somewhat) in 2004 to 93% favourable in 2006 as shown in Figure 6. The overall satisfaction increase in 2006 is reflective of the maturing and streamlining of the ADS in-class assignments, based on feedback from previous academic years; instructions have been simplified and efforts have been made to make the in-class ADS tasks more time effective by shortening them. Students commented that the immediate application of knowledge from the lecture was extremely helpful in solidifying the concepts taught.

Of interest in the response to the question was the decrease from 2005 in the percentage indicating that the software had helped very much, but the correspondingly greater increase in the helped somewhat category. Many of the students found that the complexity of ADS and the effort to get the exercises to work properly led to a loss of focus on the desired learning outcomes. Several of the students suggested a separate tutorial session to increase their familiarity with the software or more class interactive time/examples to help solve simulation questions. The simulation tool issue was exacerbated in 2006 by network, licensing, and access difficulties that prevented the students from using the software on several occasions.

Question 4: Lecture versus In-Class Assignment Balance

The chart for increased lecture time vs. in-class assignments in 2006 shows an increase in the satisfaction with the course "as is" (the *little difference* response), as shown in Figure 7. This result reflects an important development in the course this last academic year. The weighting of the final exam was reduced but a series of design reviews directly associated with the final project were introduced; this made the evaluation scheme more consistent with the teaching technique that emphasized the final project's importance. Students expressed some frustration with the the software challenges encountered; however, the emphasis was more on additional time to discuss and solve problems than on lecture material.

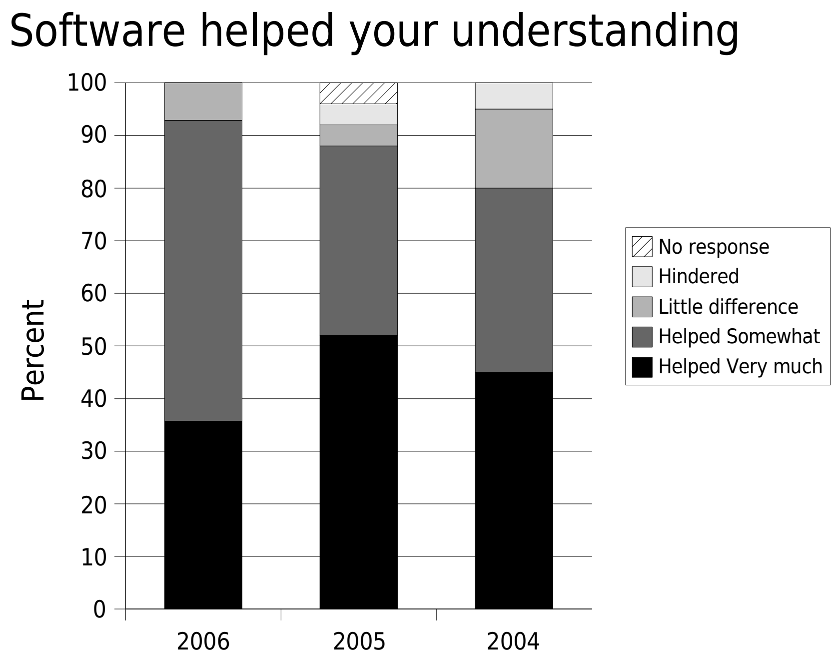

Figure 6: Percentage response to question 3

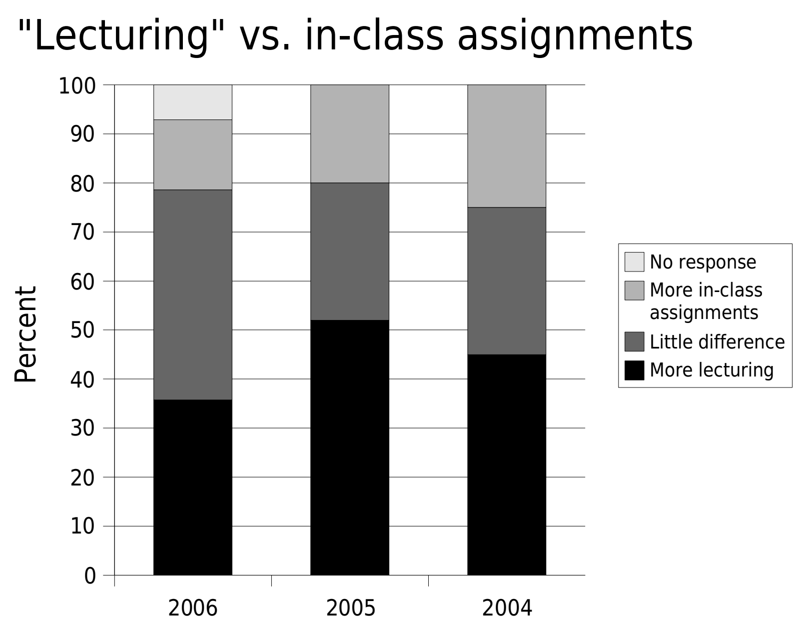

Figure 7: Percentage response to question 4

4. Evaluation of Learning Through the Final Project

The effectiveness of the final project as a learning experience experienced a significant jump in satisfaction (helped very much or helped somewhat) in 2006 (71%) when compared with 2005 (44%), as shown in Figure 8. The question also showed a significantly lower negative response (hindered) in 2006 than in 2005 (14% vs. 44%). This improvement is most likely due to the implementation of a guided term-long project based on feedback from the class of 2005. The previous year's course had been structured in such a way that the full project could only be completed after the necessary background material had been delivered. This lead to increased student dissatisfaction due to lack of time and simulation issues at the end of the course. The guided project was characterized by term-long work on assignments and periodic assessment that was directly tied to the project. This phased approach had the goal of relieving the back-end loading evident in the previous year's final project and improving the learning opportunity. This goal was partially achieved, as is evident in the following student comment: "Working toward a final goal, as the project provided, motivated me to complete each individual assignment to the best of my ability, knowing that it would be important to the end result." Unfortunately due to network and licensing issues associated with the software in the final week of the course, the final project evaluation was unable to be completed, leading to some frustration amongst the students.

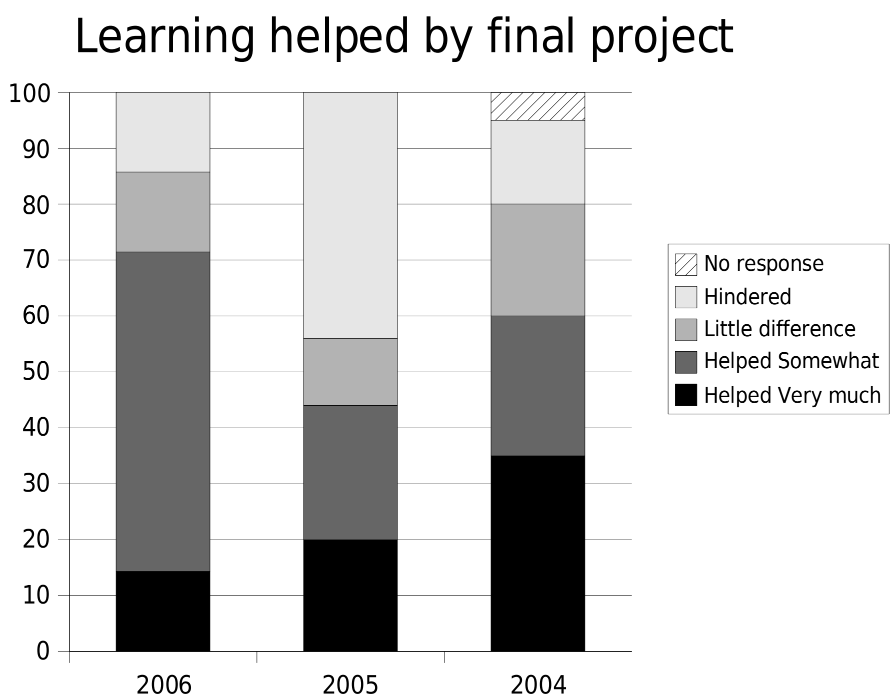

Figure 8: Percentage response to question 5

The decrease in the proportion of the highest satisfaction level in 2006 from previous years reflects the difficulties encountered with the simulation software, and the inability to complete the final project due to software issues. Several students commented that the complexity of

ADS coupled with operational issues made the final project overwhelming. This issue could be resolved by improved orientation to the simulation software and a more robust network access. Additionally, since the project was incorporated throughout the semester in 2006 as a guided project, students may have perceived the "project" portion of the class differently than in previous years.

5. Effectiveness of In-Class Discussions vs. Lectures

A new question was added to the survey in 2006 based on the increased use of discussions in class time. The question was as follows, and the possible responses are shown in **bold**:

> Do you feel that the in-class discussion improved your understanding compared to a traditional lecture format? Why or why not? **(Helped very much /Helped somewhat/Little difference/Hindered)**

The response to this query was very positive, with 93% of respondents responding "helped very much" or "helped somewhat". The students seemed to appreciate the chance for interaction with the instructor, teaching assistant, and their peers; several students that considered themselves shy found that the discussions encouraged them to make contributions and speak out. One student stated "The studio format is nice, but the big difference is the discussions and Q&A [question and answer] that helped."

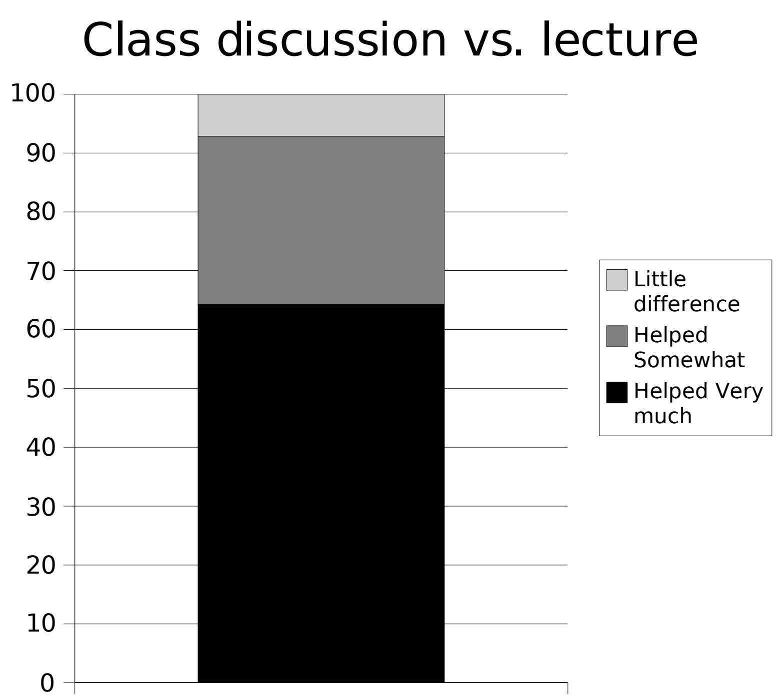

Figure 9: Response to "Do you feel that the in-class discussion improved your understanding compared to a traditional lecture format?" This question was only asked in 2006.

Discussion of survey results

The increased emphasis on group discussion in the 2006 academic year had a greater impact because of the studio layout and ease of communication than would be possible in a traditional lecture-styled course offering. Students commented that because there was nowhere to hide and they were expected to engage in class discussions, they had a responsibility to keep up to date with the course material. The increased communications therefore had two main outcomes for the students: firstly, a sense of proximity to both the instructor and fellow students that encouraged an increased amount of communication and secondly, an increased awareness of their responsibilities as contributors to the learning process.

The use of ADS as a means of both re-enforcing the lecture material and as a tool in the guided project was at times frustrating for the students because of matters that were beyond their control. The challenges associated with maintaining and upgrading a multi-site / multi-license / multi-operating system software program are significant; with proper planning and management the accessibility issue can be successfully managed. The challenges of using and becoming efficient with a new simulation tool are encountered in professional life as well. Continued review and streamlining of the in-class assignments will also aid in increasing the effectiveness of the lessons in the time allotted. The computing staff are in the process of implementing a new system that should significantly reduce these problems for next year, including the use of remote sessions running on a single stable UNIX server, rather than on multiple Windows computers.

The reduction in requests for worked problem sessions through increased lecture times may reflect the evolving evaluation of the course, where more emphasis is placed on development of analytical skills and less is placed on traditional pen and paper problem solving. Students are pragmatic in their evaluation of course material and how they will be evaluated, and will ask for more pen and paper type problems if they believe that that is the way that they will be evaluated.

The use of more frequent class discussions and the guided project were significant changes to the course structure in the last year. The open discussions allowed the students to focus on the issues that were of immediate importance to them, and actually encouraged the students to take responsibility for their learning. The discussions led to a sharing of ideas and solutions that the students found rewarding. The interactive nature of the discussions coupled with the supportive and open communication of the studio resulted in a desire by the students to stay on top of the course material and partake in the interactions. The students' suggestion to further this interaction by making fuller use of the course wiki discussion panels emphasizes the importance that is placed on communication and interaction. The guided project with periodic evaluation more closely approximates the environment the students will encounter in their professional lives, and as such the experience is valuable for preparing them for real-world expectations. The increased interaction led to an environment that the students found to be conducive to effective learning, perhaps best summed up in the following quotation:

> "I felt more like a peer learning from a respected and knowledgable (sic) coworker with this format which made the learning experience very comfortable for me."

University-wide Survey Results

All undergraduate courses at Queen's University are required to take part in a survey of student assessment of teaching. Students are asked, in the last two weeks of every course, to complete a pencil and paper multiple choice survey during class time. The questions on the survey attempt to assess the quality of teaching, though generally based on the assumption that the course is lecture-based. Each question has five possible responses, each given a numeric weight: *5=strongly agree, 4=agree, 3=neutral, 2=disagree, 1=strongly disagree*.

The mean response to the following four questions from this survey for the years 2003-2006 are shown in Figure 10. The questions were as follows:

- Overall, this is an excellent course
- Overall, this instructor is an effective teacher
- I learned a great deal from this course
- Class room questions and discussions were handled well

Historically, the mean response of all courses in the course's home department is 3.8-3.9 for these questions.

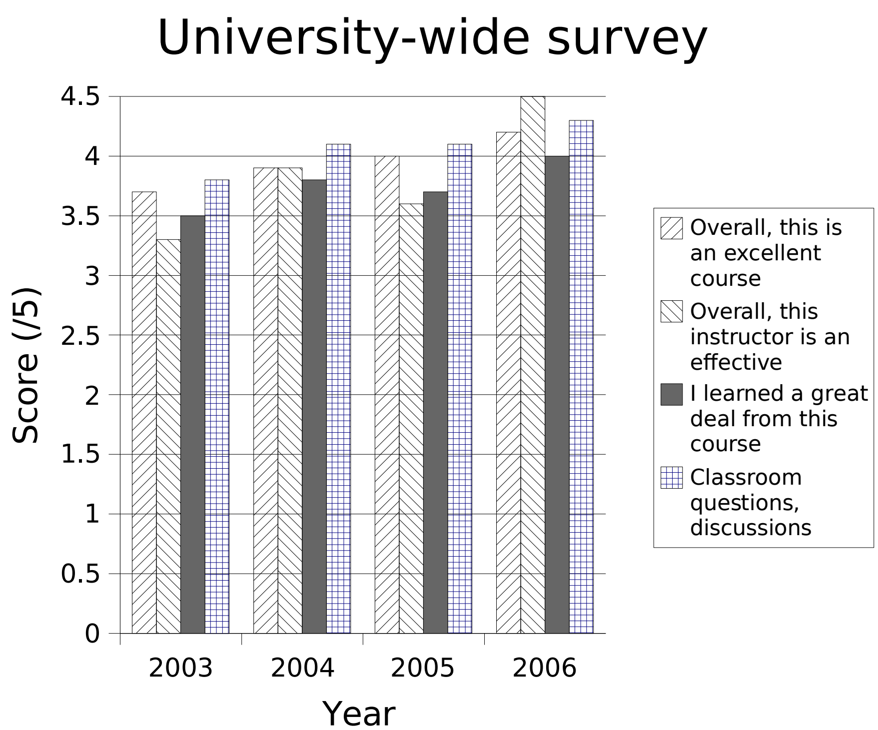

Figure 10: University wide survey results for this course.

The improvement in mean responses for these four questions over the past four years is likely attributable to two factors: (a) the instructor's improving familiarity with the material (the instructor taught the course for the first time in 2002), and (b) the evolving course format. The below average results in the university-wide survey in 2003-2005, despite the students' strong preference for the active learning style reflected in the course survey in those years, also reflect the challenge faced by the instructor when attempting to transition from a heavily lecture-based course to one requiring class participation and in-class assignments. Instructors who have no personal experience with active learning strategies and who have no formal education training may find the transition quite challenging. This instructor, like many faculty, had little experience designing in-class assignments and leading open-ended class discussions, and several years of on-the-job learning were required to develop these skills.

Conclusions

Overall, the students in the course in 2006 were more skilled in the practical aspects of microwave/RF circuit design than in previous years, and had fewer problems with the fundamentals on the final exam. Despite differences in final exams from 2002-2006, it was noted that student performance on common questions asked in all years, e.g. microwave matching network design and transistor stability analysis, was better than previous years. This may be partially attributed to improving instructor familiarity with the material, but is likely also partially due to the stronger focus on student engagement and interaction in class.

The development of this course to use a guided project format with significant in-class discussion was well received by students over the past three academic years, and far more enjoyable for the course instructor. Students responded favorably on the improved communication with other students in class, and on the constant reinforcement of the course objectives. However, heavy reliance on design software led to student dissatisfaction when computer problems prevented the completion of some course components.

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