AC 2008-75: BRIDGING THE GAP BETWEEN LAB AND LECTURE USING COMPUTER SIMULATION

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Bridging the Gap between Lab and Lecture Using Computer Simulation

Introduction

Most engineering technology courses offered today have both lecture and lab components that are taught separately in two different environments. In this setting, students are expected to meet in the lab to perform experimentations and subsequently submit their findings in the form of a lab report. If the lab experiment is not yielding the desired result, the whole experiment may need to be repeated usually under reduced time constraint and stressful conditions. Furthermore, students may not be aware to whether the problem is due to an incorrect design or a defected component. As a result, needless time and efforts could be wasted trying to figure out what is wrong with the circuit. A more serious problem would arise, if the faulty results were to go completely undetected. In this case, students will not only get an unpleasant surprise when confronted but also feel deprived from reaping the benefit of a rewarding experience. However, many of these negative outcomes can be prevented if the lab experiments are analyzed and tested using computer simulation prior to the actual lab implementation.

In this paper, we report our findings from a pilot project using computer simulation as a pre-lab assignment in an engineering technology program. Students in a two sequence electronics course were asked to perform a set of lab experiments using computer simulation software and then compare their results to real lab measurements. The educational merit of this approach is discussed with focus on the successes and lessons learned from the implementation process. Preliminary assessment results including direct and indirect measurements satisfying ABET[1] requirements are addressed. Special emphasis on the evaluation system used to test effectiveness in terms of stated objectives and learning outcomes are presented and discussed in this study.

Many studies have been performed to evaluate the merits of using computer simulations as opposed to traditional laboratory[2,3,4]. Researchers found that the "virtual lab" was as effective as the "real lab" in term of student achievement, that is, no significant difference in test scores between students using computer simulation and those who are using traditional lab equipment. However, combining both practices in a hybrid environment[5] can offer clear advantages since students will be able to compare their simulated results with actual experimentations. Therefore, our electronics courses were redesigned to use Multisim in conjunction with traditional lab activities. Multisim[6] is a popular simulation program used by many engineering educators for its friendly interactive features. It has virtual instruments resembling actual laboratory environment.

Course Assessments

Continuous improvement is an important issue for Engineering Technology programs because it defines the framework for assessment and evaluation, which is required by accrediting agencies. Consequently, an accredited program that accomplishes its mission and successfully achieves its program objectives and outcomes must have multiple levels of continuous improvement whose results are used to constantly update and evaluate the program for sustained improvement and continued success.

For our course-level continuous improvement plan, we developed assessment tools that were both *direct* measures (measurement tools that directly correlate to student performance) and *indirect* measures (measurement tools that provide additional information about student performance). Studies have shown[7] that feedback from both types of measures allows for better identification of learning and teaching challenges, which could help develop more effective strategies for course improvement. We also intentionally incorporated mechanisms to evaluate instructional strategies of poorly grasped concepts so that instruction of the course content is continuously improving as well. To this end, we emphasized the development of assessment tools, which describes the mechanisms used for course-level assessment including the use of a course-level outcomes form (CLO), a continuous improvement efforts form (CIE) and a student course outcome (SCO) evaluations form; and, finally, the implementation of the continuous improvement plan, which describes the results of the continuous improvement process during the piloted academic year. As a result of the assessment documents used to evaluate student performance, instructional methods were developed, modified and incorporated into the course for continuous improvement during the current assessment cycle.

The CLO form is completed by the instructor and submitted to the assessment committee at the end of each semester. This form states each course outcome relative to the EET program outcomes as listed in Appendix A; identifies the assessment tools that are being used to measure the student performance of each outcome and the corresponding rubric analysis result for each assessment tool. The CLO form also indicates whether the benchmark has been met or not. An example of a CLO form is given in Table 1 where the shaded entries indicate shortcomings and thus will trigger recommendation actions as shown in the column on the far right.

Table 1 - CLO Form for Electronics II

Course Name & Number:		TEET 3243 – Electronics II Spring 2007			
Course Level Outcomes	Program Outcomes (a-k)	Assessment Instrument/ Evaluation Measure	Target Level	Actual Level	Recommendation for (CIE)
1) Analyze, assemble, test and measure the operation of an operational amplifier to include voltage, current and power gains, input bias and offsets using electronic laboratory equipment.	b, c, d, e, g, k	Experiment 10 Lab reports & Exam 1 Problem 7,8 Final Exam Problem 6	2.5/4.0	**3.56** **2.78** **2.39**	Final exam format needs altered to enable complete measure of all outcomes
2) Analyze, assemble, test and measure the operation of Op-Amp feedback circuits such as inverting, non-inverting, summing, and instrumentation amps as well as integrators and differentiators.	b, c, d, e, g, k	Experiment 11 Lab reports & Exam 1 Problems 1,2,3,4,5,6,9,10 Final Exam Prob. 2 and 3	2.5/4.0	**2.81** **2.91** **1.64**	Final exam format needs altered to enable complete measure of all outcomes
3) Analyze, assemble, test and measure the operation of Op-Amp active filter circuits such as 1st and 2nd order low pass, high pass and band pass filters.	b, c, d, e, g, k	Experiment 11 Lab reports & Exam 2 Problems 1,2	2.5/4.0	**2.81** **2.96**	

4) Analyze, assemble, test and measure the operation of transistor based Class A and Class B power amplifiers, both series fed and transformer coupled types.	b, c, d, e, g, k	Experiment 12 Lab reports & Exam 2 Problems 3,4,5,6,7,8 & Final Exam Problems 5 and 6	2.5/4.0	**2.81** **2.18** **2.08**	Class B power amplifier component of instruction will be altered to include class session exercises
5) Analyze, assemble, test and measure the operation of AC to DC transformer based power converters: half and full wave rectifiers with passive filters.	b, c, d, e, g, k	Experiment 15 Lab reports & Final Exam Problem 4	2.5/4.0	**3.52** **0.41**	Final exam format needs altered to enable complete measure of all outcomes
6) Analyze, assemble, test and measure the operation of active DC to DC power regulators such as linear series and shunt circuits using transistor, Op-Amp and integrated "T" regulators.	b, c, d, e, g, k	Experiment 15 Lab reports & Final Exam Problem 4	2.5/4.0	**3.52** **0.41**	Final exam format needs altered to enable complete measure of all outcomes
7) Analyze, assemble, test and measure the operation of linear digital circuits such as comparators, linear and binary weighted D/A converters, dual slope, ladder, and sigma-delta A/D converters.	b, c, d, e, g, k	Experiment 13 Lab reports & Final Exam Problems 7 and 8	2.5/4.0	**3.22** **1.11**	Final exam format needs altered to enable complete measure of all outcomes
8) Analyze, assemble, test and measure the operation of VCO and PLL applications such as FM demodulators, frequency synthesizers and FSK decoders.	b, c, d, e, f, g, k	Experiment 13 Lab reports & Final Exam Problem 10	2.5/4.0	**3.22** **3.04**	
9) Analyze, assemble, test and measure the operation of energy conversion & electrical isolation devices such as opto-couplers, photodiodes, phototransistors, solar cells, photocells, IR emitters, LEDs, and thermistors.	b, c, d, e, f, g, k	Take Home Exam 3 Project	2.5/4.0	**3.16**	
10) Analyze, assemble, test and measure the operation of semiconductor power switching devices such as SCRs, GTOs and Triacs.	b, c, d, e, g, k	Exp. 17 Lab reports & Take Home Exam 3 Project Final Exam Problem 1	2.5/4.0	**3.44** **3.16** **3.29**	
11) Assemble and test simulations of aforementioned circuits using computer aided design tools and component libraries. Take appropriate measurements using the equivalent simulated lab instruments.	a, c, g, k	Experiment 10,11,12,15,13,16,17 Simulation reports	2.5/4.0	**2.48**	Simulation reports will be made mandatory for passing grade.
12) Produce professional (complete, concise, accurate, organized and error free) oral and written research reports.	a, b, c, d, e, g, k	Experiments(10-17) Lab and Simulation reports Take Home Exam 3 Project Report and oral presentation	2.5/4.0	**3.33** **2.48** **3.16** **3.80**	Simulation reports will be made mandatory for passing grade.
13) Participate and actively contribute to professional organizations such as IEEE	h	IEEE Student Chapter meeting April 26, 2007. Guest: Gulf- stream	2.5/4.0	**3.41**	

Instructor Comments:	
Benchmark Trigger:	If a composite score falls below 2.5, then the corresponding criterion is flagged and instructional improvements must be implemented by instructor.

The course level outcomes (1-13) entered in column 1 above are usually identified by the course instructor based on catalog description, subsequent prerequisites, and feedback from faculty and the Industrial Advisory Board.

The Continuous improvement Efforts (CIE) form tracks continuous improvements actions that have been identified based on CLO results. The instructor completes and submits a CIE form for each outcome measure that falls below the benchmark. On the CIE form, the instructor must identify the outcome that was triggered, the assessment tool that was used to measure the outcome, the corrective plan of action to eliminate the problem, and the results of implementing the action plan as shown in Table 2 with regard to CLO#4.

Table 2 - Continuous Improvement Efforts (CIE)

Course/Activity Measured: TEET3243 Midterm Exam2	Semester: Spring 2007
Prepared by: Dr. X	
What *issue* was triggered that prompted change?	CLO#4 for TEET3243: Analyze, assemble, test and measure the operation of transistor based Class A and Class B power amplifiers, both series fed and transformer coupled types.
What *tool* was used that prompted the change? (For example, student feedback, faculty observations, IAB suggestions, rubric analysis of Student performance, etc	Rubric analysis of student performance on TEET3243 Midterm Exam2 and Final Exam. Class B power amplifier component of instruction results fell below 2.5/4.0 level.
What was the *change* or improvement?	Class B power amplifier component of instruction will be altered to include class session example exercises regarding Harmonic distortion, power efficiency and thermal management, including thermal impedance and junction temperature exercises.
What was the *result of implementing* the change? (i.e. did the change correct the issue?)	CLO#4 will be emphasized in the comprehensive final exam review and rubric evaluation. Rubric result will be re-evaluated and emphasized during the next semester instruction cycle.

The student-course-outcome (SCO) evaluations form shown in Table 3 is an indirect measure. It is used to collect feedback from the student constituency based on their perception of achieving the defined course outcomes. A rubric analysis is performed and if a particular outcome falls below the benchmark, a review is initiated.

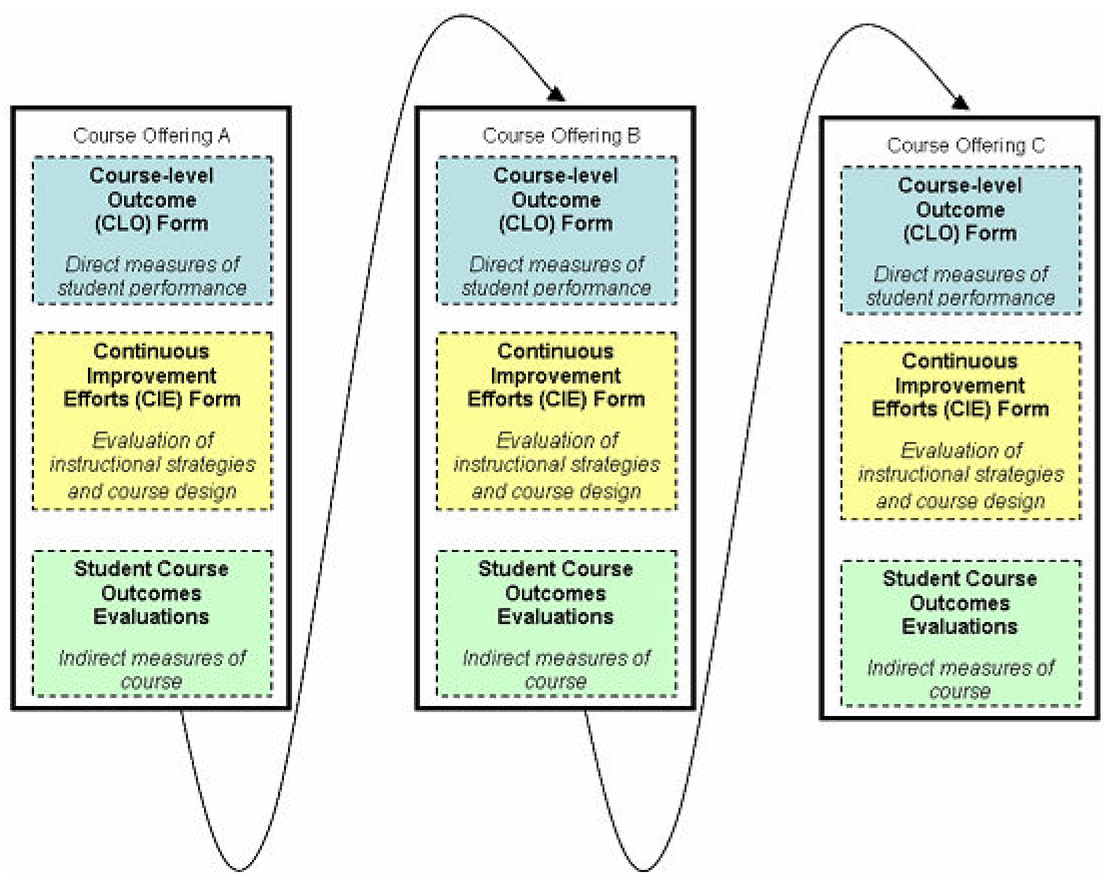
Table 3 – Student Course Outcome (SCO)

Course Name & Number: TEET 3243 – Electronics II	Prepared By: Dr. X Spring 2007 # of students 25						
	Criteria	E	G	A	P	NA	Composite
1	As a result of this course, my understanding of the internal functions of an operational amplifier to include voltage, current and power gains, input bias and offsets, can be summarized as:	13	11	1			3.48
2	As a result of this course, my understanding of Op-Amp feedback circuits such as inverting, non-inverting, summing, and instrumentation amps as well as integrators and differentiators can be summarized as:	13	12				3.52
3	As a result of this course, my understanding of the operation of Op-Amp active filter circuits such as 1st and 2nd order low pass, high pass and band pass filters can be summarized as:	16	9				3.64
4	As a result of this course, my understanding of the operation of transistor based Class A and Class B power amplifiers, both series fed and transformer coupled types can be summarized as:	8	13	4			3.16

5	As a result of this course, my understanding of the operation of AC to DC transformer based power converters: half and full wave rectifiers with passive filters can be summarized as:	10	13	2			3.32
6	As a result of this course, my understanding of the operation of active DC to DC power regulators such as linear series and shunt circuits using transistor, Op-Amp and integrated "T" regulators can be summarized as:	6	16	3			3.12
7	Analyze, assemble, test and measure the operation of linear digital circuits such as comparators, linear and binary weighted D/A converters, dual slope, ladder, and sigma-delta A/D converters can be summarized as:	6	11	8			2.92
8	As a result of this course, my understanding of the operation of VCO and PLL applications such as FM demodulators, frequency synthesizers and FSK decoders can be summarized as:	5	11	8	1		2.80
9	As a result of this course, my understanding of the operation of energy conversion & electrical isolation devices such as opto-couplers, photodiodes, phototransistors, solar cells, photocells, IR emitters, LEDs, and thermistors can be summarized as:	8	9	5		3	2.76
10	As a result of this course, my understanding of the operation of semiconductor power switching devices such as SCRs, GTOs and Triacs can be summarized as:	6	11	7	1		2.88
12	As a result of this course, my mastery of the knowledge, skills and modern tools of electrical and electronic engineering technology including an ability to use computers and computer-aided design and simulation tools effectively is (a):	16	8	1			3.60
13	As a result of this course, my ability to apply relevant knowledge and adapt to emerging applications of mathematics, science, engineering, and technology is (b):	17	7	1			3.64
14	As a result of this course, my ability to conduct experiments (use and connect standard laboratory instruments, electronic devices and equipment), analyze, interpret and troubleshoot experiments and apply experimental results to improve processes is (c):	11	13	1			3.40
15	As a result of this course, my ability to apply creativity in the design of systems, components or processes in the areas such as electronics, or electrical power and machinery is (d):	9	14	2			3.28
16	As a result of this course, my ability to function effectively in laboratory groups and/or on design teams is (e):	15	9	1			3.56
17	As a result of this course, my ability to identify, design, test, analyze, and solve technical problems is (f):	14	10	1			3.52
18	As a result of this course, my ability to communicate effectively through the submission of neat and accurate technical reports and through individual and group presentations is (g):	13	12				3.52
19	After completing this course, I recognize the need for, and an ability to engage in lifelong learning (h):	11	11	1			3.43
20	As a result of this course, my ability to understand professional, ethical, and social responsibilities is (i):	10	11	2			3.35
21	As a result of this course, I have respect for diversity and a knowledge of contemporary professional, societal, and global issues (j):	10	11	1		1	3.26
22	After completing this course, I have a commitment to quality, timeliness, and continuous improvement (k):	12	11				3.52
Benchmark Trigger:	If a composite score falls below 2.5, then the corresponding criterion is flagged and instructional improvements must be implemented by instructor.						

Figure 1 illustrates the entire course-level continuous improvement process. During course offering A, an assessment report, which consists of the three assessment forms (CLO, CIE, and SCO), are completed and submitted to the program assessment team by the course instructor. The forms are reviewed and made available to other instructors for further analysis and review. The instructor for course offering B will use the results to develop instructional methods to address student needs cited in the assessment report from instructor A. At the end of the course offering B, the course instructor will submit an assessment report for analysis and review. The cycle continues providing feedback on student learning and instruction for continuous course improvement. This process was used during the 2006-2007 academic year for course-level continuous improvement plan. The result of this process will be reported during the following 2007-2008 academic year.

Figure 1 -Flow Diagram of Course-level Assessment & Evaluation Process



As mentioned before, students were organized in teams and instructed to perform simulation as a pre-lab assignment before conducting the actual lab implementation. Due to space limitation, only the evaluation rubric for Electronics I is illustrated in Table 4. As shown, the composite scores reveal that student grades in the lab were above 3 points on a scale of 4 indicating an excellent lab performance. Furthermore, the course instructor reported that besides using lab time more effectively, students were relaxed since they were confident of the results obtained in their experiments.

Table 4 – Evaluation Rubric for Simulation and Lab Experiments

	Course: TEET 3241 – Electronics I Date: Spring Semester 2007 Evaluator: Dr. X	Activity: Lab Experiments and Simulations Rate				
Objectives	Mode	1	2	3	4	Composite
		Work shows incomplete understanding of basic concepts. No answer given.	Work shows understanding of a few basic concepts. Answers are incorrect.	Work shows understanding of most all basic concepts. Incorrect answers due to math errors.	Work shows good understanding of basic concepts. Correct answers identified.	3.04
Assemble and test a p-n junction small signal, zener and light emitting diodes to include voltage, current and power gains, input bias and offsets	Simulation 1				X	3.08
	Laboratory 1				X	3.08
Assemble and test a diode circuits such as clippers, clamps, rectifiers and voltage multipliers	Simulation 2				X	3.09
	Laboratory 2				X	3.09
Assemble and test s of Bipolar Junction Transistors (BJT) including pnp, npn, common base, common emitter, common collector configurations	Simulation 3			X		2.5
	Laboratory 3				X	3.47
Assemble and test simulations of BJT DC bias circuits to include fixed bias, emitter bias, voltage divider and voltage feedback circuit	Simulation 4			X		2.85
	Laboratory 4				X	3.24
Assemble and test s of BJT AC circuits using the re and Hybrid models to include common emitter, common base, emitter follower, Darlington and current mirror configurations	Simulation 5				X	3.25
	Laboratory 5					3.17
Assemble and test s of Field Effect Transistors such as JFET, depletion type and enhancement type MOSFET	Simulation 6			X		2.86
	Laboratory 6				X	3.19
Instructor Comments:						
Benchmark Trigger:	If a composite score falls below 2.5, then the corresponding criterion is flagged and instructional improvements must be implemented by instructor.					

Student Survey

To measure the effectiveness of using computer simulation, a student survey in Electronics I was administered towards the end of the semester. The questions of this survey are listed in Appendix B. Students' responses are tabulated below.

1. Do you believe that using computer simulation in conjunction with lab experimentations is more effective than just conducting lab alone?

Responses	Definitely	Somewhat	Not at all
14	13	1	0

2. In your opinion, did the use of Multisim make it a better lab experience for you?

Responses	Definitely	Somewhat	Not at all
14	13	1	0

3. What effects did Multisim have on your understanding of the lab experiment?

Responses	Yes, a lot	Somewhat	No effects
14	13	0	1

4. Would you recommend the use of Multisim in future lab work?

Responses	Yes	No	No opinion
14	14	0	

Future Improvement

Several lessons were learned that would be applied for future improvement. Although simple analysis was used in this study, one may easily deduce that most students are appreciative and in support of using computer simulation in combination with traditional lab environment. They all wanted the practice to continue, but they can also be critical. Therefore, educators must keep students engaged and adjust their teaching techniques accordingly. In fact, the best lessons may be learned from reading students' comments and suggestions as listed in Appendix C.

Although computer simulation has shown to have a positive impact on student performance, its effects on students' attendance and retention was not established and thus, require further investigation. Moreover, further examination of the variant in student lab evaluation relative to the overall course requirement may be warranted. The course-level continuous improvement process has proven to be very effective in targeting problems in conceptual student learning during the 2006-2007 academic year. However, there are several improvements that can be made to improve the overall efficiency of the process. For example, a real-time implementation of the plan of action described on the CIE form should be incorporated to benefit current students struggling with conceptual understanding. The course-level continuous improvement process is good for improving instructional strategies and increasing student comprehension, however it increases the workload for instructors. Consequently, autonomous means for collecting and submitting data would be very useful for instructional efficiency. Future work will explore the incorporation of these options to increase the effectiveness of the process and provide a more streamlined approach to course-level, and ultimately, program-level continuous improvement.

Conclusion

Studies performed to evaluate the merits of using computer simulations as opposed to traditional laboratory found no significant difference. Nevertheless, combining both practices in a hybrid environment can offer clear advantages. In this paper, a pilot project for using computer simulation as a pre-lab assignment in an engineering technology program was presented. Students in electronics courses were asked to perform a set of lab experiments using Mutlisim and then compare their results to real lab measurements. The educational merit of this approach was discussed with focus on the successes and lessons learned from the implementation process. Assessment results including direct and indirect measurements satisfying certain accreditation requirements were addressed. Special emphasis on the evaluation system to test effectiveness in terms of stated objectives and learning outcomes were discussed. It was shown that students using this hybrid approach were not only satisfied but also able to use lab time more effectively and achieve higher scores. Future work will explore the development of autonomous means to streamline the collection of data and submission process.

References

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[6] National Instruments: http://www.electronicsworkbench.com/

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Appendix A

General skills students are expected to possess upon graduation from the EET program:

(a) An appropriate mastery of the knowledge, skills and modern tools of electrical and electronic engineering technology including an ability to use computers and computer-aided design tools effectively
(b) An ability to apply relevant knowledge to achieve feasible and practical results, while also adapting to emerging applications of mathematics, science, engineering, and technology
(c) An ability to plan and conduct experiments in a disciplined manner (use and connect standard laboratory instruments, electronic devices and equipment), analyze, interpret, troubleshoot and apply experimental results to improve processes using sound engineering principles
(d) An ability to apply creativity in the practical, cost effective and reliable design of systems, components or processes in the areas such as electronics, or electrical power and machinery
(e) An ability to function effectively in laboratory groups and/or on design teams with members and tasks sometimes separated in time and space
(f) An ability to identify, design, test, analyze, and solve technical problems using knowledge gained from a broad understanding of engineering disciplines including and outside electrical engineering technology
(g) An ability to communicate effectively through the submission of professional (neat and accurate) technical reports and through individual and group presentations.
(h) A recognition of the need for, and an ability to engage in lifelong learning with an awareness of the significance of membership and contribution to IEEE and other similar professional organizations
(i) An ability to understand professional, ethical, and social responsibilities
(j) A respect for diversity and knowledge of contemporary professional, societal, and global issues
(k) A commitment to quality, timeliness, and continuous improvement

Appendix B

Student Questionnaire

1) Do you believe that using computer simulation in conjunction with lab experimentations is more effective than just conducting lab alone? a) Definitely----- b) Somewhat--------- c) Not at all…….
2- In your opinion, did the use of Multisim make it a better lab experience for you? a) Yes, a lot----- b) Somewhat------ c) Not at all
3- What effects did Multisim have on your understanding of the lab experiment? a) Increased-------- b) Decreased-------- c) No effects-----------
4- Would you recommend the use of Multisim in future lab work? a) Yes--- b) No----- c) No opinion------------
5- What do you like MOST about Multisim used in this course and why?
6- What do you like LEAST about Multisim used in this course and why
7- What do you recommend to make the use of Multisim more effective?

Appendix C

Comments made by students when answering questions 5-7

5) What do you like MOST about Multisim used in this course and why?
- Simulate circuit without equipment error
- Its accuracy and simplicity
- Multisim makes it easier to see what you are doing and you don't have to worry about faulty parts like you do in lab
- Quickly and easily test and understand circuits
- I like it as a pre-lab
- It is an easier way to calculate the AC and DC parameters
- Easier to recreate diagrams with the program. The fact that is a computer program
- It allowed you to see if your physical results were close to the theoretical
- It is another learning tool in applying what we do
- You learn how to design the circuits and it helps to find the actual value you suppose to get in lab
- The experiment can be performed quicker and more accurate

- It gives an accurate view of the lab
- It was easy to learn and use. Aided physical lab experiments

6) What do you like LEAST about Multisim used in this course and why?
    - Hard to match real life components
    - We did not use it enough
    - Multisim let you see the circuits easier but the material is still difficult and hard to grasp
    - Learning how to use it at first. Sometimes connecting components is quirky
    - Sometimes the connections in the circuits will be connected , but the addition of DMM can alter the results if not given enough space
    - Sometimes the values may be wrong. If the circuit is not correctly connected
    - I wished we could learn more
    - Nothing
    - It takes time to conduct the circuits
    - Perhaps, it was net being used to its full potential. It was only being used to measure currents and voltages

7) What do you recommend to make the use of Multisim more effective?
    - Multisim course offering
    - All lab done with Multisim because the lab equipment is outdated
    - The teacher should go through an example to show where to measure some voltages and how to build some components
    - Use it in class as well as lab
    - Better explanations
    - Students should perform all labs as Multisim before performing the measurement potion in the lab so students can expect what type of results to get
    - Tutorial class or a day to learn the software
    - Computers in lab so that we can actively use it
    - Teach on how to use it more
    - Maybe spend more time to explain Multisim
    - Do one or two more advanced Multisim labs taking advantage of its other features
    - An in depth review of Multisim in class or lab
    - Classes on how to use Multisim