

AC 2010-227: DEVELOPMENT AND ASSESSMENT OF A PCB LAYOUT AND MANUFACTURING LABORATORY MODULE IN INTRODUCTORY ELECTRIC CIRCUITS FOR EE AND NON-EE MAJORS

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Development and Assessment of a PCB Layout and Manufacturing Lab Module in Introductory Electric Circuits for EE and non-EE Majors

Abstract

In standard introductory electric circuits laboratories for electrical engineering (EE) majors and non-EE majors, prototype boards are typically used to construct and test electric circuits. Students typically do not learn how to design and manufacture Printed Circuit Boards (PCB) that are commonly used in more sophisticated design projects and other engineering applications. This paper will present the development and assessment of a PCB layout and manufacturing laboratory module that has been used in introductory electric circuits laboratories for EE and non-EE majors. The feasibility of integrating the new PCB layout and manufacturing module into the electric circuit course will be discussed. An experiment has been designed and conducted to assess the impact of the PCB module. A survey with questions from the Motivated Strategies for Learning Questionnaire (MSLQ) supplemented with additional questions was used to measure students' motivation and the impact of the PCB module on student learning. In Winter quarter of 2009 at Cal Poly, two lab sessions for sophomore and junior non-EE engineering majors were taught by an instructor with an experimental group that designed a real PCB for one of their circuit design experiments and a control group that implemented all of the experiments using prototype boards. In Spring quarter of 2009 at Cal Poly, two lab sessions for EE majors at the sophomore level were offered by the same instructor with an experimental group that designed and built a PCB for one of their circuit design experiments and a control group that performed all experiments using prototype boards. Data have been collected and analyzed for these four student groups. Results indicate the inclusion of the PCB module did not impact the student's ability to achieve any of the course or laboratory learning objectives. Though no statistically significant difference in student's motivation was found between the experimental group and the control group, the results strongly indicate that students enjoyed the introduction of the PCB design module. Furthermore, students report they have a higher confidence in their ability to design printed circuit boards and they are more likely to design PCBs in other course projects as part of their senior projects.

Introduction

Based on the experience of the Network Performance Research Laboratory (NetPRL) faculty at Cal Poly and feedback from Cal Poly's computer engineering industry advisory board, a skills and knowledge gap exists between the engineering curricula and professional practice. Students in electrical and computer engineering are often not prepared to develop complex systems requiring custom printed circuit boards. The majority of electrical engineering programs teach basic electronics laboratories using solderless prototyping boards and circuit analysis using simulation software such as PSpice. There is a different skill set needed to design a prototype circuit as compared to designing and implementing an actual electronic device using Printed Circuit Board (PCB) tools and techniques.^{1,2} To fill the gap, several universities started to develop electronic manufacturing laboratories and offer courses for electrical and computer engineering students.^{1,3-9} But all of these courses are upper-division and most of them are technical electives.

The authors believe that there is a need to have a required lower-division PCB design and manufacture experience in engineering education. Today, some engineering students learn how to use PCB design tools on their own if they are motivated to do so. If students are formally introduced to PCB design and manufacturing as part of their coursework, they will be much more likely to design PCBs for course projects and their senior design projects, thus enabling them to create more reliable and sophisticated design projects. In addition, good engineering design should take into consideration the construction and manufacturing processes for a well rounded learning experience.

This paper presents a PCB layout and manufacturing laboratory module that can be integrated into a traditional lower-division electric circuit laboratory course for both EE and non-EE students. The paper includes the implementation of this module into a sophomore level circuit design course for electrical and computer engineering majors, EE 242, and in a junior level electronics laboratory course for non-EE majors, EE 361. The feedback and assessment data of the PCB module are presented in this paper.

Development of the PCB Module

The PCB module includes a tutorial and two separate PCB projects. The first project is geared towards teaching the students how to use the PCB Design tool called DipTrace and how to assemble a printed circuit board using soldering stations in the lab. The second project allows the students to design, layout and assemble a printed circuit board-based Operational Amplifier (Op Amp) circuit.

Before beginning a PCB project, the students first review an online tutorial to learn how to use the DipTrace PCB Computer Aided Design (CAD) tool. The DipTrace tutorial can be accessed online at <http://idesign.calpoly.edu/dip-trace/>.¹⁰ To prepare students to build their electronic device, they also view a soldering video and are given instruction on soldering and the assembly of printed circuit boards.

The purpose of the first continuity tester PCB project is to guide students in designing, manufacturing, assembling, and testing an electronics system implemented on a PCB. The continuity tester, as shown in Figure 1, lights the red LED when the button is pushed if the red and black leads on the left detect electrical continuity. The continuity tester consists of the 12 components listed in the bill of materials in Table 1. The schematic for the continuity tester project is shown in Figure 2. Students are given the schematic of the project and all components needed to build the continuity tester project. Students are guided to create libraries of all the necessary components, and to layout the printed circuit board. The students do not fabricate the PCB they design for the continuity tester, but are given a prefabricated PCB to assemble and test. The prefabricated PCB is used for the continuity tester project to reduce the time and cost needed to fabricate custom PCBs for the first project. After designing, assembling and testing the continuity tester, the students have gone through the full development cycle for a simple PCB project.

The second project is to implement a 4-bit DAC circuit using Op Amps and a Digital Counter. The 4-bit DAC circuit is one of the four circuits typically included in one of the Op Amp

Experiments in EE 361. The students lay out a PCB for the DAC Op Amp circuit using DipTrace, use the services on the web to fabricate the custom PCB that they design, assemble their custom board, test the circuit and rework if needed, and make the required measurements that are asked of them in the Op Amp experiment. Figure 3 shows the implementation of a 4-bit DAC circuit using a custom PCB designed in EE 242. Figure 4 includes the schematic of the 4-bit DAC circuit.

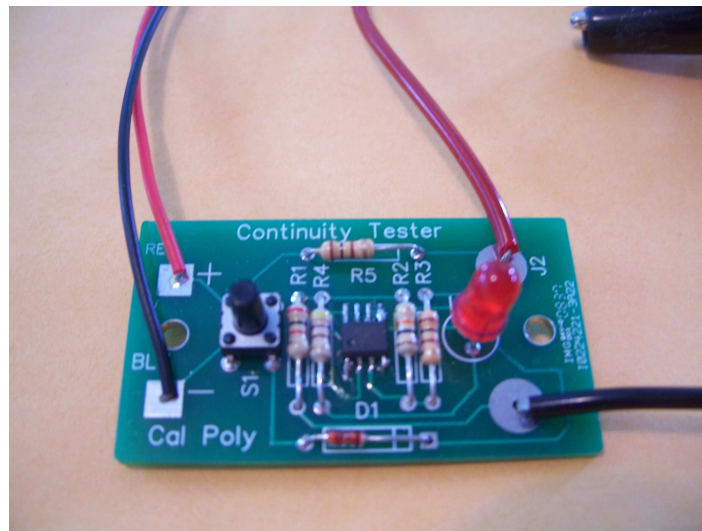


Figure 1. Continuity Tester Project

Table 1: Bill of Materials of the Continuity Tester

| ITEM | QTY. | REF. | DESCRIPTION |
|------|------|------|--|
| 1 | 1 | D1 | Diode, 1N914 |
| 2 | 1 | D2 | LED, red, SIZE 1-3/4, Panasonic LN21RPHL |
| 3 | 1 | J1 | Test lead, red, 12"L |
| 4 | 1 | J2 | Test lead, black, 12"L |
| 5 | 1 | J3 | Cable, 9V battery snap |
| 6 | 1 | R1 | Resistor, 2 K ohm 1/4W, 5% tolerance |
| 7 | 1 | R2 | Resistor, 10 K ohm 1/4W, 5% tolerance |
| 8 | 1 | R3 | Resistor, 100 ohm 1/4W, 5% tolerance |
| 9 | 1 | R4 | Resistor, 470 ohm 1/4W, 5% tolerance |
| 10 | 1 | R5 | Resistor, 100 ohm 1/4W, 5% tolerance |
| 11 | 1 | S1 | Switch, Panasonic EVQ-PAC09K |
| 12 | 1 | U1 | IC, LM311M, surface mount component |

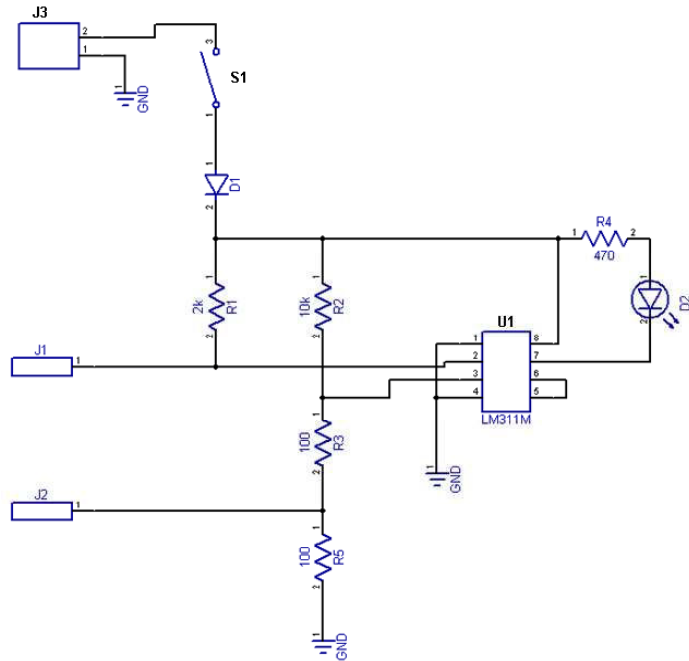


Figure 2. Schematic of the Continuity Tester Circuit

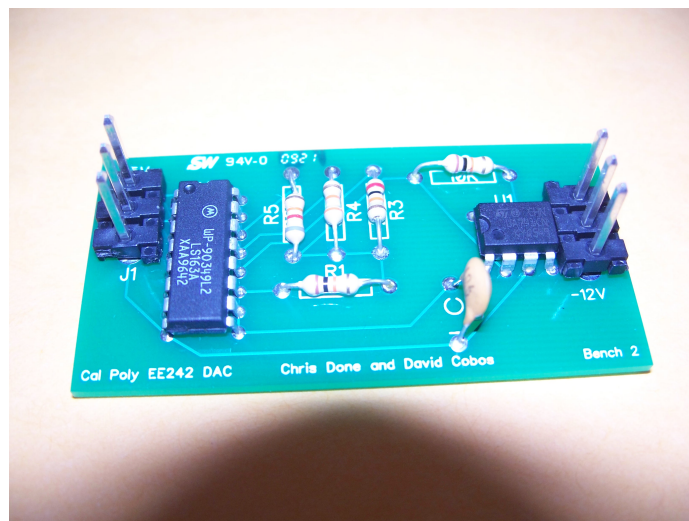


Figure 3. 4-bit DAC Op Amp Project

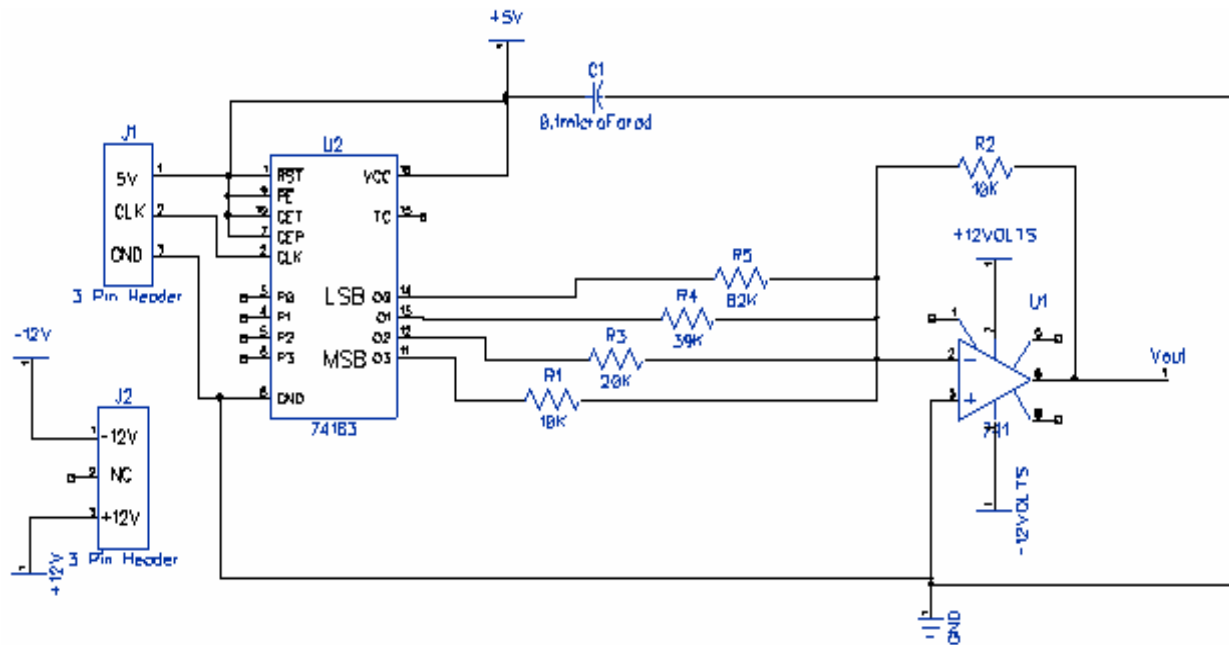


Figure 4. Schematic of the 4-bit DAC Op Amp Circuit

Implementation of the PCB module

To incorporate the PCB module into the introductory electric circuits laboratory, the lab syllabus and schedule was modified. A comparison of the original EE 242 lab schedule and the modified EE 242 lab schedule for electrical and computer engineering majors is shown in Table 2. The DAC Op Amp circuit with the PCB design module replaced the Energy Transfer & Storage experiment in the standard EE 242 lab schedule. Electrical and computer engineering students analyze Op-amp circuits in EE 241, a prerequisite of EE242.

The comparison of original EE 361 lab schedule and the modified EE 361 lab schedule for non-EE majors is shown in Table 3. The 4-bit DAC circuit is one of the four Op-amp circuits analyzed by students in EE 361. The other three Op-amp circuits include a voltage follower, a non-inverting amplifier and an inverting amplifier. Instead of constructing all four Op-amps circuits on a prototype board, students in the modified lab plan design and assemble the DAC Op Amp circuit using a PCB and construct the other three Op-amp circuits on a prototype board.

The learning objective of the DAC circuit portion of the experiment is for the students to have both a conceptual and mathematical understanding of the transfer function for a digital to analog converter. Students are expected to be able to derive the transfer function in a pre-lab exercise and they are also expected to explain the staircase output in a post-lab question. In a post-lab question, students are expected to explain how to smooth the staircase-like DAC output.

Table 2: Comparison of the original lab schedule and the modified lab schedule of EE 242 for electrical and computer engineering majors

| Week | Original Lab Schedule | Modified Lab Schedule |
|------|--|---|
| 1 | Syllabus | Lab 1: Syllabus & PCB design with DipTrace |
| 2 | Lab 1: energy storage and transfer circuit | Lab 2: PCB assembly of continuity tester |
| 3 | Lab 2: Transient in RC circuits | Lab 3: Transient in RC circuits |
| 4 | Lab 3: AC steady state power | Lab 4: AC steady state power, Continuity Tester PCB design due |
| 5 | Lab 4: Phasor diagrams | Lab 5: Phasor diagrams |
| 6 | Lab 5: Computer simulation of 3-Phase circuits using PSpice | Lab 6: Computer simulation of 3-Phase circuits using PSpice |
| 7 | Lab 6: Low-pass and high-pass RC filters | Lab 7: Low-pass and high-pass RC filters, Op-Amp DAC PCB Design Review |
| 8 | Lab 7: Parallel resonance | Lab 8: Parallel resonance |
| 9 | Lab 8: Characteristic of parallel RLC circuit using pulse excitation | Lab 9: Characteristic of parallel RLC circuit using pulse excitation |
| 10 | Laboratory final exam | Laboratory final exam, Assembly and testing of Op-Amp DAC Circuit |

Table 3: Comparison of original lab schedule and the modified lab schedule of EE 361 for Non-EE majors

| Week | Original Lab Schedule | Modified Lab Schedule |
|------|---|--|
| 1 | Syllabus | Syllabus and Lab 1: Use of the Oscilloscope and designer box familiarity |
| 2 | Lab 1: Use of the Oscilloscope and designer box familiarity | Lab 2: PCB design with DipTrace |
| 3 | Lab 2: Operational Amplifiers Part 1 | Lab 3: Operational Amplifiers Part 1 and 2 combined |
| 4 | Lab 3: Operational Amplifiers Part 2 | Lab 4: PCB assembly of continuity tester |
| 5 | Lab 4: Diode circuits | Lab 5: Diode circuits |
| 6 | Lab 5: Bipolar junction transistor circuits | Lab 6: Bipolar junction transistor circuits |
| 7 | Lab 6: Logic gates and flip-flops | Lab 7: Op-Amp DAC PCB Design Review |
| 8 | Lab 7: Shift registers and memories | Lab 8: Logic gates and flip-flops |
| 9 | Schedule for holidays or catch-up | Lab 9: Shift registers and memories |
| 10 | Laboratory final exam | Laboratory final exam, Assembly and testing of Op-Amp DAC Circuit |

Assessment of the PCB Laboratory Module

In order to assess the impact of the PCB Module, two experiments were conducted. The first experiment was conducted in the EE 361 laboratory during the Winter quarter of 2009, while the second experiment was conducted in the EE 242 laboratory during the Spring quarter of 2009. In both experiments, the control group sections and experimental group sections were both taught by the same instructor. The control group section followed the standard schedule while the experimental group section followed the modified schedule. The students signed up for one of these lab sections independently without prior knowledge of the experiment. Thus, students

are considered to be randomly selected between the experimental and control lab sections. On the first day of class, the students in the experimental sections were informed about the PCB module and all of the students in the experimental sessions agreed to participate in the PCB module experiment. In the EE 361 lab, a total of 24 students were in the control group and 18 students were in the experimental group. The number of students from various engineering majors for both the EE 361 experimental group and control group is listed in Table 4. Note that since this is an electrical engineering survey course taken by engineering majors other than electrical and computer engineering students, each of the two groups happened to have a different distribution of engineering majors. In the EE 242 lab, eight electrical engineering students and ten computer engineering students were in the control group while nine electrical engineering students and nine computer engineering students were in the experimental group.

The authors created a survey with questions from the Motivated Strategies for Learning Questionnaire (MSLQ)¹¹ supplemented with additional questions to measure students' motivation and the impact of the PCB module on student learning. The survey developed for this study is included in the Appendix. A pre-test was administered at the beginning of the quarter and a post-test was administered after the students completed the final exam. In addition to the survey, the instructor's feedback and observations and student evaluation comments related to the PCB module were reviewed and are presented in this paper. Finally, comments related to the PCB module from the student evaluations were also reviewed.

Table 4. Student majors for EE 361 experimental and control groups

| Major | Number of Students | |
|--|--------------------|--------------------|
| | Control Group | Experimental Group |
| Mechanical Engineering | 21 | 11 |
| Aerospace Engineering | 3 | 2 |
| BioResource & Agricultural Engineering | 0 | 5 |
| Total | 24 | 18 |

Results and Discussion

An Analysis of Variance (ANOVA)¹² is used to analyze the modified MSLQ survey results for the students in both the control and experimental sections of EE 242 and EE 361. The p-value in an ANOVA analysis is used as a measure to identify how likely the sample results are from different populations, assuming the null hypothesis is true. The null hypothesis, in this study, is that there is no difference in average score among the control group and the experimental group or difference from the pre-test to post-test for a particular group. If a p-value is less than α -threshold (a specified significant level, 0.05 in this study, or 95% confidence level), the null hypothesis is rejected, and the samples are determined to be from different populations indicating a statistical difference in the results of a comparison for a particular question on the survey.

Table 5 summarizes the ANOVA results for all 53 questions in the EE 242 modified MSLQ survey. The small p-value of group (experimental vs. control) means that the experiment group and the control group were composed of different student populations. The small p-value of test time (pre-test vs. post test) means that the lab module made a statistical difference (either better

or worse). The interaction between the test time (pre-test vs. post-test) and the groups (control group vs. experimental group) indicates whether the experimental group performed better or worse than the control group after the lab module, which is the objective of this study. Since no p-value of the interaction is less than 0.05, it indicates that the introduction of the PCB module did not impact the student's ability to achieve any of the course or laboratory learning objectives of the EE242 lab.

Table 5. Summary of the ANOVA Results for EE 242 all 53 Questions

| Question Item | P-Value | | | Question Item | P-Value | | |
|---------------|------------------|------------------------|-------------|---------------|------------------|------------------------|-------------|
| | Exp. vs. Control | Pre-Test vs. Post-Test | Interaction | | Exp. vs. Control | Pre-Test vs. Post-Test | Interaction |
| #1 | 0.651 | 0.221 | 0.797 | #28 | 0.313 | 0.935 | 0.959 |
| #2 | 0.447 | 0.066 | 0.447 | #29 | 0.503 | 0.057 | 0.503 |
| #3 | 0.289 | 0.976 | 0.773 | #30 | 0.901 | 0.061 | 0.922 |
| #4 | 0.117 | 0.826 | 0.768 | #31 | 0.364 | 0.671 | 0.839 |
| #5 | 0.876 | 0.876 | 0.300 | #32 | 0.015 | 0.000 | 0.926 |
| #6 | 0.056 | 0.251 | 0.867 | #33 | 0.602 | 0.944 | 0.406 |
| #7 | 0.958 | 0.169 | 0.555 | #34 | 0.316 | 0.964 | 0.883 |
| #8 | 0.211 | 0.412 | 0.867 | #35 | 0.124 | 0.208 | 0.731 |
| #9 | 0.030 | 0.030 | 0.688 | #36 | 0.430 | 0.776 | 0.580 |
| #10 | 0.373 | 0.077 | 0.373 | #37 | 0.030 | 0.224 | 0.592 |
| #11 | 0.361 | 0.879 | 0.879 | #38 | 0.259 | 0.259 | 0.845 |
| #12 | 0.649 | 0.285 | 0.711 | #39 | 0.544 | 0.801 | 0.415 |
| #13 | 0.813 | 0.542 | 0.210 | #40 | 0.009 | 0.220 | 0.099 |
| #14 | 0.513 | 0.513 | 0.513 | #41 | 0.124 | 0.094 | 0.943 |
| #15 | 0.007 | 0.023 | 0.792 | #42 | 0.850 | 0.120 | 0.787 |
| #16 | 0.305 | 0.222 | 0.423 | #43 | 0.491 | 0.126 | 0.751 |
| #17 | 0.007 | 0.326 | 0.793 | #44 | 0.067 | 0.245 | 0.463 |
| #18 | 0.404 | 0.841 | 0.807 | #45 | 0.251 | 0.569 | 0.569 |
| #19 | 0.082 | 0.770 | 0.381 | #46 | 0.005 | 0.512 | 0.992 |
| #20 | 0.343 | 0.845 | 0.390 | #47 | 0.029 | 0.711 | 0.142 |
| #21 | 0.041 | 0.643 | 0.508 | #48 | 0.140 | 0.211 | 0.482 |
| #22 | 0.391 | 0.988 | 0.873 | #49 | 0.024 | 0.181 | 0.181 |
| #23 | 0.337 | 0.985 | 0.729 | #50 | 0.529 | 0.100 | 0.360 |
| #24 | 0.212 | 0.912 | 0.952 | #51 | 0.020 | 0.663 | 0.663 |
| #25 | 0.033 | 0.048 | 0.979 | #52 | 0.471 | 0.131 | 0.629 |
| #26 | 0.002 | 0.174 | 0.946 | #53 | 0.245 | 0.948 | 0.301 |
| #27 | 0.988 | 0.196 | 0.319 | | | | |

Table 6 summarizes the ANOVA results for all 53 questions in the EE 361 modified MSLQ survey. It is noted that the control group scored higher than the experimental group on 14 questions that are related to the students' confidence in their study and problem solving skills, knowledge of course material, and competitiveness against other students. This difference is likely related to the different student populations in the EE 361 experiment group and the control group lab sections as shown in Table 4.

Table 6 shows that the p-value of interaction for Question 47 is 0.000 in the EE 361 lab. Recall that question 47 is that “*I feel that I have a basic understanding of the design and manufacturing process for Printed Circuit Boards (PCBs).*” Figure 5 shows the interaction plot for Question 47. It is clear that the students in the experimental group reported a gain in their understanding of the PCB design and manufacturing process while the understanding of the PCB design and manufacturing process in the control group did not change significantly.

The results listed in Table 5 indicate that the interaction variable p-value for Question 47 was greater than 0.05 in the EE 242 lab. The authors note that at Cal Poly both the electrical and computer engineering students take a basic electronics manufacturing course in their freshman year that includes the design and assembly of printed circuit boards before they begin their circuit analysis courses. Therefore, the PCB module incorporated into the EE 242 lab is their second experience with PCB design and assembly. The authors believe that this likely accounts for the higher pre-test scores on Question 47 which may account for the large p-value on the interaction of Question 47 for the EE 242 experimental group. Therefore, the results for Question 47 from EE 361 better reflect the experience of engineering students that have no prior experience with PCB design and manufacturing.

Table 6. Summary of the ANOVA Results for EE 361 all 53 Questions

| Question Item | P-Value | | | | Question Item | P-Value | | |
|---------------|------------------|------------------------|-------------|--|---------------|------------------|------------------------|-------------|
| | Exp. vs. Control | Pre-Test vs. Post-Test | Interaction | | | Exp. vs. Control | Pre-Test vs. Post-Test | Interaction |
| #1 | 0.043 | 0.384 | 0.573 | | #28 | 0.959 | 0.682 | 0.769 |
| #2 | 0.502 | 0.397 | 0.371 | | #29 | 0.066 | 0.837 | 0.518 |
| #3 | 0.084 | 0.103 | 0.250 | | #30 | 0.240 | 0.757 | 0.886 |
| #4 | 0.028 | 0.250 | 0.322 | | #31 | 0.038 | 0.821 | 0.939 |
| #5 | 0.442 | 0.576 | 0.326 | | #32 | 0.304 | 0.498 | 0.304 |
| #6 | 0.011 | 0.643 | 0.265 | | #33 | 0.005 | 0.269 | 0.924 |
| #7 | 0.004 | 0.966 | 0.712 | | #34 | 0.491 | 0.459 | 0.527 |
| #8 | 0.013 | 0.805 | 0.805 | | #35 | 0.548 | 0.111 | 0.292 |
| #9 | 0.047 | 0.532 | 0.339 | | #36 | 0.342 | 0.783 | 0.632 |
| #10 | 0.710 | 0.099 | 0.677 | | #37 | 0.146 | 0.011 | 0.730 |
| #11 | 0.015 | 0.395 | 0.786 | | #38 | 0.687 | 0.905 | 0.905 |
| #12 | 0.085 | 0.156 | 0.318 | | #39 | 0.715 | 0.584 | 0.584 |
| #13 | 0.150 | 0.012 | 0.376 | | #40 | 0.029 | 0.573 | 0.373 |
| #14 | 0.055 | 0.500 | 0.870 | | #41 | 0.724 | 0.037 | 0.614 |
| #15 | 0.466 | 0.217 | 0.859 | | #42 | 0.724 | 0.121 | 0.724 |
| #16 | 0.912 | 0.720 | 0.879 | | #43 | 0.362 | 0.078 | 0.810 |
| #17 | 0.790 | 0.017 | 0.343 | | #44 | 0.268 | 0.055 | 0.189 |
| #18 | 0.065 | 0.167 | 0.105 | | #45 | 0.249 | 0.863 | 0.293 |
| #19 | 0.258 | 0.638 | 0.895 | | #46 | 0.260 | 0.713 | 0.713 |
| #20 | 0.341 | 0.534 | 0.809 | | #47 | 0.093 | 0.000 | 0.000 |
| #21 | 0.666 | 0.257 | 0.969 | | #48 | 0.859 | 0.000 | 0.368 |
| #22 | 0.298 | 0.734 | 0.603 | | #49 | 0.015 | 0.317 | 0.598 |
| #23 | 0.001 | 0.934 | 0.934 | | #50 | 0.076 | 0.666 | 0.302 |

| | | | | | | | | |
|-----|-------|-------|-------|--|-----|-------|-------|-------|
| #24 | 0.397 | 0.649 | 0.242 | | #51 | 0.070 | 0.583 | 0.172 |
| #25 | 0.346 | 0.083 | 0.499 | | #52 | 0.291 | 0.284 | 0.969 |
| #26 | 0.239 | 0.165 | 0.070 | | #53 | 0.751 | 0.877 | 0.399 |
| #27 | 0.465 | 0.756 | 0.701 | | | | | |

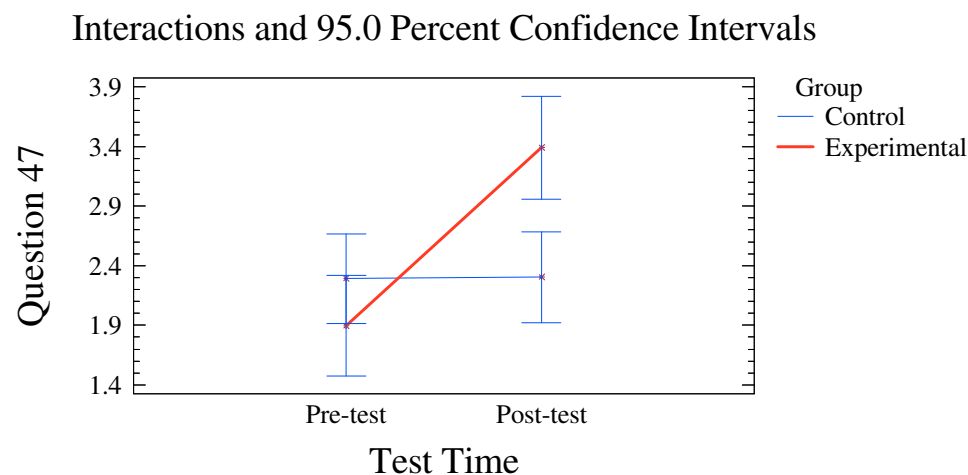


Figure 5. Interaction plot for EE 361 Question 47: *“I feel that I have a basic understanding of the design and manufacture process for Printed Circuit Boards (PCBs).”*

The instructor observed the students’ ability to successfully complete the PCB module within the constraints of a laboratory course and noted the student feedback he received. The instructor reported that most of the students were excited about doing the PCB module. In fact, several students in the control group said they were disappointed that they were not going to perform the PCB module in their laboratory section. The instructor further reported that in the EE 242 experimental section, seven of the nine PCBs were excellent designs and that the other two designs required minor rework to get the circuit to work. All student groups were able to design and build operational circuits using the PCBs module and all groups completed their required circuit measurements and observations.

The instructor believes that students took pride in their finished PCBs and some students commented that their printed circuit boards were “cool!” Approximately 5 out of the 18 students in EE 242 verbally told the instructor that building a PCB helped them in their understanding of circuits, and specifically made the circuit diagrams and problems encountered more tangible and less mysterious. In addition, several students said that it would be a good idea to permanently add the PCB module to the circuit analysis course or somewhere else in the curriculum. The instructor also had one student come to his office to ask questions about designing a PCB for another class project.

The students also had the opportunity to provide anonymous comments through the course evaluations. There were several positive and no negative comments on the student evaluations related to the PCB module. Comments on the course evaluations related to the PCB module include: “[The] PCB part rocked.” “Constructing and designing the PCBs was a lot of fun.”

“Continue to do that [PCB Module].” “New material in the lab was good to learn more about the subject (PCB design).” “PCB design was fun – nice diversion from the standard labs.”

Summary and Recommendations

A study has been done to assess whether a Printed Circuit Board design and assembly module could be incorporated into an electric circuit laboratory for electrical and computer engineering students and in an electronics survey course for other engineering majors at Cal Poly. The PCB module was successfully integrated into two existing laboratories with a minor impact to the overall laboratory activities and schedule. The trial demonstrated that the students were successful at designing and building a printed circuit board for an Op Amp experiment integrated into the existing laboratory experience. Though no statistically significant difference in student's motivation was found between the experimental group and the control group, the results strongly indicate that students enjoyed the introduction of the PCB design module. In addition, our assessment indicated that all of the course learning objectives were met with the inclusion of the PCB module and that students report a better understanding of PCB design and manufacturing. Students who performed the PCB module believe that they are more likely to design PCBs as part of their other laboratory experiments and design projects than the students in the control groups.

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Student Survey

Please rate the following items based upon this class.

Your rating should be on a 7-point scale where

1= not at all true of me to 7=very true of me.

| | Not at all True of me | | | | | | Very True of me | |
|--|--------------------------|---|---|---|---|---|--------------------|--|
| 1. Compared with other students in this class I expect to do well. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| 2. It is important for me to learn what is being taught in this class. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| 3. I like what I am learning in this class. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| 4. I'm certain I can understand the ideas taught in this course. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| 5. I think I will be able to use what I learn in this class in other classes. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| 6. I expect to do very well in this class. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| 7. Compared with others in this class, I think I'm a good student. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| 8. I am sure I can do an excellent job on the problems and tasks assigned for this class. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| 9. I think I will receive a good grade in this class. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| 10. I think that what I am learning in this class is useful for me to know. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| 11. My study skills are excellent compared with others in this class. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| 12. I think that what we are learning in this class is interesting. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| 13. Compared with other students in this class I think I know a great deal about the subject. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| 14. I know that I will be able to learn the material for this class. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| 15. I worry a great deal about tests for this subject. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| 16. Understanding this subject is important to me. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| 17. I work on practice exercises and answer end of chapter questions even when I don't have to. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| 18. Even when study materials are dull and uninteresting, I keep working until I finish. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| 19. Before I begin studying I think about the things I will need to do to learn. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| 20. I often find that I have been reading for class but don't know what it is all about. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| 21. I find that when the teacher is talking I think of other things and don't really listen to what is being said. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| 22. When I am studying a topic, I try to make everything fit together. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| 23. I work hard to get a good grade even when I don't like a class. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| 24. When reading I try to connect the things I am reading about with what I already know. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |

For the following subjects and skills, please circle the number corresponding to the response that best describes how confident you are of your abilities in the subject or skill.

| | Not Strongly Confident | | | | Strongly Confident | | |
|--|---------------------------|---|---|---|-----------------------|---|---|
| 25. Design | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 26. Engineering | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 27. Writing | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 28. Speaking (Making Presentations) | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 29. Computer Skills: Word | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 30. Computer Skills: Excel | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 31. Computer Skills: PowerPoint | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 32. Computer Aided Design: (drafting, electronic layout, etc.) | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 33. I am confident about my current study habits or routine. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 34. I am confident about my ability to communicate effectively. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 35. I am confident in my ability to construct and evaluate basic electronic circuits. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 36. I am confident in my ability to succeed in engineering. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 37. I am confident about my ability to interpret electronic measurements. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 38. I am confident that I will graduate with a Bachelor of Science degree. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |

For the following statements, please circle the number corresponding to the response that best describes how strongly you disagree or agree with the statement.

| | Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|----------------------|----------|-------|-------------------|
| 39. I have no desire to change to another major (biology, English, chemistry, art, history, etc.). | 1 | 2 | 3 | 4 |
| 40. I have strong problem solving skills. | 1 | 2 | 3 | 4 |
| 41. I am good at designing things. | 1 | 2 | 3 | 4 |
| 42. I am gaining experience in the use of electronic measurement and test equipment. | 1 | 2 | 3 | 4 |
| 43. I feel that I understand the limitations of electronic measurement and test equipment. | 1 | 2 | 3 | 4 |
| 44. I understand how to analyze and evaluate data in this course. | 1 | 2 | 3 | 4 |
| 45. I am able to present my findings in a professional manner. | 1 | 2 | 3 | 4 |
| 46. Creative thinking is one of my strengths. | 1 | 2 | 3 | 4 |
| 47. I feel that I have a basic understanding of the design and manufacturing process for Printed Circuit Boards (PCBs). | 1 | 2 | 3 | 4 |
| 48. I believe there is a benefit to designing printed circuit boards over using prototype wiring boards. | 1 | 2 | 3 | 4 |
| 49. I plan to design printed circuit boards for class projects. | 1 | 2 | 3 | 4 |
| 50. I plan to design printed circuit boards for projects that are not related to course work. | 1 | 2 | 3 | 4 |
| 51. I feel that I could quickly learn how to use other printed circuit board software tools to design circuits. | 1 | 2 | 3 | 4 |
| 52. I am very motivated to do well in this course. | 1 | 2 | 3 | 4 |
| 53. I feel that I will become a successful engineer. | 1 | 2 | 3 | 4 |

54. Major: (Please write in): _____

55. Year in School:

- ☐ Frosh
☐ Sophomore
☐ Junior
☐ Senior
☐ Graduate Standing

56. Do you have previous experience with printed circuit boards?

- ☐ No
☐ Yes

These last demographic questions are optional:

57a. Gender:

- ☐ Female
☐ Male

57b. Ethnicity/Race: (Please write in): _____