Introducing Freshman EET Students to Design and Software Simulation Tools

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Abstract:

This paper will discuss the introduction of electronics simulation software and a design experiment into a Freshman level Electrical Engineering Technology circuits course. This design experiment replaces three laboratory experiments, and requires students to use software simulation as a tool. Students are now introduced to design, the use of software simulation, formal report writing, and peer evaluation through this project at the beginning of their college career.

The introduction to circuit analysis ("Electrical Circuits I" - *EET 102*) course at the Purdue University Electrical Engineering Technology Department at Indiana University Purdue University Indianapolis is structured with a lecture section and a laboratory section like many similar courses nationwide. The laboratory section of Circuits I was structured with 16 weekly laboratory assignments, performed by student teams typically consisting of two to three students. The laboratory section is designed to correlate with the material covered in the lecture section.

The course has undergone two major revisions over the past year. The first was to introduce electronic simulation software, namely Electronics Workbench, into the laboratory section. The other change involved restructuring some of the labs into a group design project. This paper will discuss each revision and the advantages and disadvantages of each.

Electronic Simulation Software:

Electronics Workbench electronic simulation and design software (Interactive Image Technologies, LTD.) was introduced to give the students an introduction to tools that they have at their disposal to assist them in the laboratory and through homework problems. Based on previous experience, students who are introduced to tools such as simulation and design software earlier are more likely to utilize and less likely to be intimidated by the tools available to them.[1]

Laboratory manuals were set up as 16 separate weekly experiments with specific requirements for student laboratory teams. One of the challenges to introducing Freshman students to a topic as new and unique as this software during one of their first EET courses is that *everything* is a brand new topic at this level. Many students adopt a "quickest way out" attitude in the laboratory, because the structure of weekly "cookbook" laboratory experiments works quite favorably to the student that doesn't understand the connection between theory and hands-on, or is not particularly interested in exploring the purpose of the hands-on experience. Successfully introducing this software tool to students requires careful thought on how and when to first implement it into the laboratory. In order to introduce the software to the students, a new laboratory experiment was developed which lead the student teams through a brief tutorial of Electronics Workbench. One of the keys to successful implementation is to use the software as an available tool rather than as stand-alone laboratory experiments, and in order to accomplish this, the only experiment that is not primarily a hands-on laboratory is the “Introduction to Electronics Workbench” experiment. This experiment is approximately half way through the course, and once introduced, students are encouraged to add an Electronics Workbench simulation to their subsequent experiments. The flow of most experiments is now: perform calculations to obtain expected values, simulate the circuit on Electronics Workbench, and build and measure circuit characteristics. The software, along with the calculations, assists the students in verifying the construction of their circuits and the correctness of their calculated values. Many students now routinely use Electronics Workbench to verify laboratory and homework assignments, and some have purchased a student version for their use at home.

There are many references available to assist in the implementation of this software into any circuit analysis course, including software models of many circuits contained in texts used in these courses.[2, 3]

The Group Design Project:

The other major revision introduced the students to design at the Freshman level, thereby introducing students to the differences between design projects and other technology and engineering projects.[4] This project also addresses two additional University-wide goals: to foster a “learning community” environment among the students, and to introduce the students to the necessity of technical writing. IUPUI is primarily a commuter campus with a high percentage of older, employed students, and therefore, it can be difficult to foster peer to peer relationships. Introducing students to their peer group through the project can encourage students to work with their peers not only in the laboratory, but through other courses as well. Other studies have also shown that students who are introduced to design early in the curriculum have found the development of student teams and teamwork skills increase their sense of personal involvement, and their understanding of the material studied in the design process.[5]

The class assigned to the project was given two weeks in the laboratory to complete the project, as well as an additional two hours during the third week if necessary. For the most part, groups of 5 students were formed based on the overall grades of the students at that time. A few changes were made to ensure a mix of demonstrated technical skills and abilities within a group, and specifically exclude any usual lab partners from being in the same group. All of the groups did some work outside of class time, and had the design, construction, and measurement complete in the first two weeks.

The project was assigned enough points to make it equivalent to five ordinary laboratory assignments. The objective of the project was:

PROJECT OBJECTIVE:

1. To theoretically design and analyze one circuit to demonstrate KVL, KCL, voltage division, current division, mesh and nodal analysis, superposition, and Delta / Wye and/or Wye / Delta conversions.

2. To experimentally verify all of the above techniques.

3. To document this design, analysis, and experiment in a formal report.

Each group was to design a circuit of sufficient complexity to adequately demonstrate all of the above principles, analyze the circuit, build the circuit, and take sufficient measurements to experimentally verify the results.

One major difference between a typical experiment and this project was that, although these students were in the first course in Electrical Engineering Technology, they were totally responsible for each step in the design, construction, and presentation. While they were to have the design checked, the instructor would not tell the group if the project was adequate to meet the requirements. The group would be entirely responsible for final decisions, and the groups were totally responsible for their design. Because this project was in an academic setting, the instructor was available for assistance if needed; however, if the design was not sufficient to demonstrate all of the required principles, they would not find out until receipt of the graded final report. This was done to more closely resemble a project as it may be found in industry; a group may be judged entirely on their presentation of the project upon its completion. Holding each group accountable for their design seemed to be one of the strongest success points of this project - many students who had marginal to weak performances in lab prior to this project were challenged and responded with stronger lab performances during and after the project.

Groups were to have their project checked at four points in the development:

- Design
- Data Format
- Calculations
- Measurements

Data Format was a simple checkpoint to generate some discussion between the group members about their choices of format. Throughout the semester, students have recorded data directly on electrical schematics, or in a table or a list format. The Calculation and Measurement checkpoints were similar to the Design checkpoint in that they were not checked for completeness. The purpose of checking the group at these points was to remind each group to be sure enough measurements had been taken to do the circuit analysis required in the report. If there was a lack of sufficient measurements or calculations, the group would not know until they received their final reports back, but these checkpoints gave the instructor a timely opportunity to make suggestions to the group if their work was not sufficient.

Because this is an introductory course, students were strongly encouraged to work in their weakest areas. The project description passed to the students read:

> *Since everyone has different strengths and weaknesses, this is your chance to work out any weaknesses with help! Team members should concentrate on areas that they are weak in - if you are unsure about measuring currents through resistors, you should assume this responsibility. In this case, team members should offer assistance whenever possible.*

This was another highlight of the project. The students were told that the skills learned in this class will travel with them through most of the classes that they would take in the future, and that this was the time to learn those necessary skills. Therefore, if they were at all unsure of their understanding or their ability to use some knowledge or skill, they were to sign up for that within their group. This worked very well - some of the individual success stories show that the students who truly followed this advise benefited to a great extent from their project experience.

Learning Communities:

The project offered an opportunity for students to work with others in their class whom they had not previously talked to. The goal of linking the students into a learning community is to give the student a peer group in which they will feel more comfortable. This serves the student and the University by increasing the student's chances to succeed in graduating and improving student retention.

Separating students into groups is not enough to ensure that there will be effective group interaction, as the student who is content to "coast" through the laboratory watching their partner perform the experiment is just as content to see someone else get the hands-on experience. Other students in the group benefit from the standpoint that they are able to assist group members, which in turn serves to build confidence in their abilities and increase their understanding of the areas they are able to present to others.

Each student was required to evaluate their performance as well as the performance of each team member. This was to be strictly confidential; the evaluation sheets were not passed back to the students, and they were told not to discuss their evaluations of other students. They were to honestly describe what they did, what each other team member did, and assign a grade to themselves and their teammates, and they were asked to specifically discuss if any member of the team signed up for a section of the lab where they were weak. Some guidelines were specified:

- They may not simply say, "We all deserve an A". If that is indeed the case, supply data to back it up.

- These evaluations were to be kept confidential. They were instructed not to discuss what they wrote with each other. If a student asked what was written about them, they were told to say "I am not allowed to discuss individual evaluations" or "I said that you deserved an A".

- These could either be turned in with the reports in a sealed envelope or e-mailed to the instructor.

- They were asked to discuss if any member of the group signed up for a section of the lab where they were weak.

- Finally, they were told that the instructor was present for most of the working sessions, and that the amount of participation was already known by the instructor. Therefore, these evaluations should agree with the observations of the instructor. If the instructor's evaluations were wrong, all of the teammates should agree on the individual's performance.

In one section of the course, for example, there were two cases where the instructor's evaluation did not agree with the self-evaluation of the student. In one case, the instructor's opinion (along with the four evaluation sheets from the student's teammates) agreed that the student's participation was well below that student's self-evaluation; in the other case, the four evaluations from the group agreed that a student's contribution was excellent, where the instructor's opinion was that the performance was strictly average. Much of this student's contribution was outside of the classroom. The first student received an poor score for participation, while the second received an excellent score.

Students tended to be very generous with the evaluations of their teammates. The average evaluation from the class writing on the standard experiment was a B+ to an A for the student's teammates, and a B- to a B for the individual student. A few of the evaluations discussed specific contributions but did not assign a specific grade to themselves or their partners.

Technical Writing:

Most industry recruiters rank "effective communication" among their top three characteristics for a new employee.[6] Effective writing skills cannot be learned exclusively from a Technical Writing course. It is difficult to convince a student of the importance of effective written communication if the student's only experience in writing is in a writing course.

Each student was to prepare a formal written report on the project as though they were solely responsible to report for their group. Students were given guidelines to follow on the format of the report, and were directed towards writing texts and the Engineering and Technology Writing Center; a resource available to all students to assist them in preparing written reports.

The reports had one overall guideline: they were to be *concise* and *complete*. The students were reminded of this frequently. While the reports needed to cover each assigned area, they also should not include excessive "fluff" to lengthen the report. In this regard, students were given a *suggested* length rather than a *required* length. The students were free to arrange their reports as they felt appropriate. The students were encouraged to follow some standard format such as:

Title / Cover Page
Abstract
Introduction
Results
(including data, calculations, and analysis)
Equipment List
Conclusion

It was stressed to the students that the most important parts of a report are typically the Abstract and Conclusion, as these are sometimes the only sections read. Rather than suggest a particular format to present the raw data and calculations, students were to combine these sections as they thought best.

Since this is an introductory course, the quality of the written reports varies tremendously. Also, introducing a formal report in an introductory course allows the students an opportunity to experiment with a format that they may feel is more appropriate than the suggested format and receive constructive feedback from the instructor. One technical writing text says, “There is no ANSI standard for a formal technical report”.[7]

Project Grading and Feedback:

The main purpose of assigning a formal report in this class was to introduce the students to the type of report that they may have to prepare regularly upon graduation. The formal reports were graded in the usual way, by writing suggestions and questions in the margins of the report itself. This method works fine for grading the report, but it may not provide much constructive feedback to a student. Each student received an evaluation sheet with a quantitative evaluation of their work along with their graded report. Each student was evaluated in four areas, with short notes on constructive criticism:

Grammar/Spelling: This was worth 10 points (of a possible total of 50 points)
Typical feedback: Most comments pertaining to grammar and spelling were written directly on the reports. Most feedback in this area involved writing to the appropriate audience, try to write in third person unless necessary, and suggestions such as ‘only use one side of the paper’.

Technical Writing: This was worth 15/50 points.
Typical feedback: It was sometimes difficult to separate feedback for technical writing from general writing feedback. Technical writing feedback examples were “Need to write on a technical level, not so personal” (do not write “I really had fun doing this experiment”), “Need an Abstract and/or Conclusion” if these sections were skipped; “Should include discussion of differences in theory & measurements” where they were presented, etc.

Technical Content: This was worth 15/50 points, 5 of which were for an on-time submission.
Typical feedback: Technical comments. These primarily involved a lack of data to support a calculation or conclusion, or skipping analysis of a required area (such as Current Division). Care was taken to put comments into the proper areas of General Writing, Technical Writing and

Technical Content.

Participation: Students were told that this was based primarily on the instructor's observations, The evaluations of the student and the team members were also taken into account here. Most students received a 9 or 10 of a possible 10 here (meaning that they contributed their fair share to the group).
Typical feedback: Typical responses here were "No major problems" or "Excellent". In the few cases of students who had below satisfactory participation scores, their score was given with comments stating that it was based primarily on their self-evaluation or the observations of the instructor. Other student evaluations were never mentioned here, although they were considered as part of the score.

Category	Comments	Grade
Grammar/Spelling... General writing	Minor corrections - see report	8/10
Technical Writing: How well were the technical points expressed?	Calc's/Data look great Def'n page looked great No distinction between measured & calculated - did you *build* both circuits for Delta <-> Wye?	12/15
Technical Content: Accurate thorough measurements, descriptions, calculations	Delta <-> Wye - should measure V's and I's throughout the circuit to prove they were identical	13/15
Participation: Primarily based on lab instructor's observations	No problems	9/10
	Total	42/50

Table 1: Evaluation sheet turned back to students with their graded reports

It is anticipated that this more detailed feedback will prove to be more beneficial to the students than comments on a graded report. This gives the student a one page evaluation which can be reviewed before writing a future report.

Results of the Project:

Overall, results of the project were excellent. Each group presented a design that was sufficiently complex to show all of the required principles. The quality of the formal reports varied, but was satisfactory given that this was the first experience for many of the students outside of a technical writing class.

It is difficult to accurately measure the performance improvement of one class due to the project, especially short term. The true measure of success of introducing a design experience into the course will be seen as improved performance and understanding in subsequent classes.

Evaluations from Individual Students:

One student that showed one of the most striking improvements was in a student whose self-evaluation said:

> "The role I played during this lab was to wire the circuit board. This was one of the areas I was weak. ... I feel more confident now about doing this. Actually, this lab project was very beneficial for me in learning more about mesh analysis, nodal, and KCL. Overall this project was very good for me in helping to identify my weak spots."

This student was comfortable allowing her lab partner to perform the majority of tasks in typical laboratory experiments prior to the design project, and this seemed to carry over into a lack of confidence on exams. After this project, her performance in the laboratory and on exams improved dramatically. She had been strictly an average performer on exams until she received an 82% on the third exam (average: 65%) and a 75% on the final exam (average: 70%).

This project allowed opportunities for inconspicuous or quiet students to excel in a team environment. One of these students had evaluation comments from teammates similar to this:

> "<This student> participated by discussing and drawing possibilities for circuit designs which would meet the objectives. He then came prepared, having done nearly all calculations. This was a major effort."

This student's self-evaluation was very diplomatic, but did give the message that the group was to come up with designs and calculations prior to a meeting, and he was the only group member prepared. The solution was for the group to use his circuit and calculations. This student is normally above-average in laboratory performance and exam scores, but when placed in a team environment he was able to shine through as a group leader.

There were few students who had below satisfactory performances. One of the students basically did not participate at all individually or within the team, and this was reflected in evaluations from her teammates.

An additional student had trouble with the teamwork aspect of the project. He typically works alone at a very fast pace. He seemed to want to get the assignment and move on, reporting to the group as necessary, rather than working as part of a team. His technical report was satisfactory. However, in the group environment, he turned out to be one of the most criticized students. He did not turn in a self-evaluation.

Miscellaneous Points and Summary:

The students did not receive the project requirements prior to the first working day in the laboratory. Typically, the laboratory experiment to be studied was found in the student laboratory manual, allowing some students to study and prepare ahead of time. If the teams were given the requirements early, some students may work ahead, which could discourage others from becoming involved.

One of the most important tools in evaluating a long-term laboratory project is the use of student evaluations. Some of the groups did a significant amount of work outside of the class time, and the instructor realistically has no way to know how much each student participated. Students were generally pleased to provide feedback on other members of the group, and were typically generous when evaluating other team members. However, when problems did occur, they usually pointed them out, some more tactfully than others. If student evaluations are to be used, they *must* be kept strictly confidential to be effective.

It is certainly more difficult and time consuming to grade formal reports, especially if the goal is to provide meaningful feedback to students. It is anticipated that breaking the overall grade into different areas and supplying constructive feedback in these areas will help the students be better prepared for future reports.

The students seemed to welcome the opportunity to assume total responsibility for their work rather than having it monitored or supplied to them. The circuits designed were sufficient to show all of the requirements (although some reports did not address all of the requirements).

Assigning students to teams without their typical laboratory partners allowed students to work with their peers to a greater extent, and these relationships can assist individual students to feel less alone through their entire college career. This has been shown to increase a student's chances to eventually graduate, thereby improving retention.

Many of the students were able to benefit from the suggestion to work in their weakest area, especially when it was pointed out that the skills they are learning apply through most of the technology courses they will take in the future. The students were told that they are expected to know some skills upon completion of this class, and if they were unsure, this was their best opportunity to learn.

Conclusions:

Students going through an introductory circuits course are usually presented with concepts that they are totally unfamiliar with, and many think of this course as a struggle. Students are now introduced to electronics software simulation tools earlier in their studies, giving them a very useful tool to use throughout their college career. This also serves to decrease feelings of intimidation as new software tools are introduced farther down the line.

Introducing a team project into the curriculum allows students to work with their peers, which improves student understanding for students who work more effectively within a team of their peers, as well as those students who are instructing and assisting them. This project also gave students the opportunity to work through a project that they are responsible for, and an opportunity to strengthen areas in which they may be weak.

Numerous industry surveys and articles cite three of the most sought after qualities in graduates as

- ability to work effectively in teams,
- confidence to think and reason through a problem, and
- ability to communicate

This project gave students some experience in all three of these areas. Many studies have suggested that students need more experience in these areas while in school, although it is sometimes tough to convince the students that this is the case. If projects like this are introduced into many laboratory courses, students should graduate better prepared to move into the workplace and make a contribution to their employer.

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