Confidence-Building in a Circuits Course

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Abstract

In this paper we look at how students develop professional confidence while learning circuit analysis.
Usually a sophomore or a junior, the typical student takes a circuit analysis course after completing a series of basic science courses where rigor and details are strongly emphasized. So these students feel "comfortable" when they understand every line of a proof or a solution. Skipping even one comma, or using a shortcut, may hinder full understanding. The student's ensuing sense of "discomfort" is a desirable and necessary stage, one that develops curiosity, scientific skepticism and a lifetime quest towards fundamental and basic understanding.
In a circuit course, students are faced with a new perspective: to become proficient in analysis and creative in design and to account for an extraordinary number of circuit techniques and variations, students have to rely on shortcuts, on sketches of solutions and, in general, on a somewhat fuzzier approach. The accomplished and expert circuit analyst and designer often employs intuition, the trace of an idea or a solution to confidently produce a successful result. The solution to a circuit problem or design is sometimes finalized when just a quick sketch of the mental process is completed.
In this paper we analyze this interesting dichotomy in the perception of acquisition of knowledge and in the enhancement of skills, as it develops from basic science courses to circuits courses. We suggest techniques and tools to build desired skills and confidence. We also discuss the possibility to quantify students' reactions, attitudes and increased confidence, within a set of measurable performances and surveys.

Introduction: a daydream scene

Sometimes, hopefully not frequently, when I teach an introductory physics or engineering class in a quantitative subject such as mechanics, electromagnetism, or thermodynamics, I might feel the class is getting "lost". Few students seem to follow and the rest of the class nervously looks at their watches or distractedly daydreams. Is this *deja vu*? Is this a familiar scenario? Do not worry; no great damage has been done. In the next class I will presumably start over from the point where the class disengaged and the lost bits of knowledge will be recovered.

Continuing this daydreaming of my own, suddenly another scene strikes my imagination: here I see one particular student, the one who was always interrupting in that introductory class three years ago, asking me to repeat the proof, or to scroll back to a previous slide. I was going too fast, he told me once, after dropping by to my office. Now this student is a senior, and I am sitting in the crowd listening to his/her Senior Project presentation. What a performance! How he (or she) presents the material smoothly, professionally and eloquently! Even those complex

equations and proofs needed to sustain the theoretical basis of the project are displayed in a well-orchestrated and balanced way, giving the essentials and skipping the unimportant details! I wonder how the miracle has happened again. The fragile, insecure freshman has transformed in four years into a well-rounded engineer who radiates professionalism, competence and confidence. Yes, competence and confidence, those are the key words.
Wait! Suddenly one of the freshmen in the crowd raises his hand and asks the senior presenter if he/she could repeat that proof and rewind a couple of slides back. The senior sighs and complies, repeating the explanation without skipping any detail. There is some impatience in the presenter's voice. Then his/her eyes, wondering into the audience, encounter mine. We both cannot avoid a smile. The irony of the situation is apparent to us. Unspoken and unnecessary wisdom whispers in our ears that a confidence-building miracle has just been completed, while the four-year path for another miracle has just started to unroll.

Learning in a circuit analysis class

How is this daydream scenario linked to teaching Circuit Analysis?
Well, the typical circuits students completed a series of basic science courses where rigor and details were emphasized and where they usually understood every line of a proof or a solution.

In a circuits course, they are faced with becoming proficient in analysis and creative in design. They must learn many circuit techniques and variations, and must learn to rely on shortcuts and on sketches. The accomplished and expert circuit analyst and designer mostly project an intuition, the trace of an idea or a solution or a design to a level of confident implementation. The solution to a circuit problem or a design is felt "in the bag" when just a quick sketch of the mental process is projected or outlined.

Research and understanding over the last few decades has transformed the way we teach and interact in the classroom. Educators nowadays mostly consider the learning process as a shared discovery and triggering of knowledge involving teachers and students in complementary roles. This is in contrast to previous models which envisioned knowledge being "given" to students by learned (and autocratic) professors.

The Accreditation Board for Engineering and Technology (ABET,) has, by its standards, encouraged professional maturity upon graduation. In the accreditation process, an institution must critically expose its curriculum and convince the accreditation team that professional requirements are met. The accreditation process invites a cross-referenced analysis of all courses and activities, including details of each course's contribution to the various professional attributes. Therefore, it is only natural, nowadays, to write syllabi that refer to contributions of the courses to various identified professional criteria. This process is important since it provides guidance for distributed, complex curricula and uniformity of evaluation for similar institutions.

This process can (and probably should) be pushed even further, in that instructors should present material in a way that also enhances desired professional skills and attitudes in the student. Each course has a different nature, "personality" and flavor. Identifying and recognizing which professional attributes can be discovered, appreciated and facilitated in a given course would focus and improve the instructor's planning and delivery throughout the course.

With this background and in this context I started thinking about what features and opportunities are embedded in a circuits course. Some thoughts have evolved from daydreamed insights and inspirations, towards facilitating and developing desired professional traits and attitudes in the students.

A place to start could be a critical analysis of the contributions of a circuits course to the a-k attributes, mentioned under ABET criterion 3 (Program Outcome and Assessment.)

The text in the ABET publication "Criteria for accrediting engineering programs" reads as follows:

"Engineering programs must demonstrate that their graduates have:

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) an ability to design a system, component, or process to meet desired needs
(d) an ability to function on multi-disciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice."

I could link to each attribute, and clearly see how any circuits course should be relevant in strongly contributing to (a), (b) (c) (e) and (k). I further could convince myself that "Circuit Analysis" at Elizabethtown College, being taught in an integrated studio-class-lab setup, does significantly contribute also to attributes (d), (f), (g), (i) and (j).

However, I still felt that something was missing. Since I was an undergraduate student I always looked with awe and respect to professors, engineers or even advanced students who seemed to have a "wizardly" ability to analyze and understand circuits. One look at the schematics of a circuit and everything looked clear to those (not too many) "wizards". No need for extensive circuit analysis; no painful node-voltage or mesh-current techniques or Thévenin equivalent…The "wizards" looked like they "felt" the solution, they "lived" the currents flowing in the circuits and they mysteriously could characterize anything happening in the schematics.

Over the years, and already upon completing my undergraduate studies, I felt how a process of deeper understanding, backed by stronger confidence in my acquired skills was developing. And then through graduate school, professional engineering jobs, high-tech industry, academic research and teaching positions, all of these enhanced my circuit analysis skills. As usual, the ultimate mastery of a subject comes when one teaches a course for a few years. So, after teaching

"Circuit Analysis" for a number of years, I felt I could compete with those "wizards" in circuit analysis. On a pedagogical professional level, I have always kept a hidden, unconscious curiosity over how this "wizardry" develops. As a professor, observing and interacting with classes of students who struggle, at first, in understanding and integrating multiple techniques of circuit analysis, I always enjoyed recognizing one or two students in the class who, naturally and unequivocally are on the path to achieve quickly and painlessly the "wizardry" status. Similarly, I enjoy, maybe even more, observing other students, who obviously have not been gifted by an intuitive, instinctive predisposition to analyze circuits, but who all the same develop mastery and expertise in circuit analysis by hard work and a sustained process of confidence building.

In these times of genome sequencing, when almost every day you read in the newspaper about the attribution of a character trait or a behavioral mode or a given skill to a specific gene, somebody might wonder if they will ever discover something similar for circuit "wizards." Without crossing out any possible surprises in the future, after years of observation of different student learning patterns and of experimenting various teaching models, I am convinced that every average student can eventually become a circuit "wizard". It is well known and documented that different individuals approach learning and cognitive integration in different ways. Some learn fast and naturally, but might easily and quickly saturate. Others might have a long learning curve, but the level achieved by repetitive efforts keep growing and deepening. For all these different types of learners, confidence building is a key word and a key ingredient. The path for a student to become a circuit 'wizard" or, in less mystic terms, a masterful, proficient circuit analyst, passes through and intensive process of skill and confidence building.

Professional confidence building in the context of a circuit analysis course transcends a simple psychological state of mind or mood. Without backing from specific cognitive research results, I dare to state that confidence building goes to the very heart of the cognitive process, at least for the particular problem of developing circuit analysis skills. Confidence building, developed through repetitive and special emphasis learning, most probably changes the way our analysis and creation processes develop. It is one of the bases for deeper analyses, and for leap of faiths in addressing audacious conjectures.

The first ingredient necessary for developing confidence in one's professional skills is undoubtedly old–fashioned traditional learning. Without getting familiar with the topics involved, the techniques used, the results expected, it is very difficult to acquire any additional skills or to enhance competence and confidence. Sometimes, and circuit courses surely do fall in this category, repetitive learning is required to fully integrate new material. But many additional techniques and methods can facilitate the right combination of skill enhancement and confidence building that is needed to eventually become a master circuit solver.

Enhancing confidence building in a circuit analysis class

What techniques and tools can be employed to facilitate the emergence, buildup and enhancement of professional confidence and mastery in a circuit analysis class?

Here is my first tentative list:

- Present the material in different formats. Different learning schemes or tools affect different individuals in different ways. Some learners are more visual learners, some are more listening types, some like abstraction, and some need visualization and examples.

- Solve some problems and circuits with different techniques. This expands the perspective of how to attack a problem and induces a comparison among different strategies. It also builds confidence in that it unveils the large amount of tools available for use.

- Start the course with solutions presented in great detail, with no skipped lines or missed bits; gradually proceed to less detailed solutions, where two or three steps are condensed. Whenever students show discomfort or misunderstanding, review the details and stress the reasoning and strategy behind the condensing technique.

- Always approach the solution of a circuit problem by a qualitative analysis first, pushing the limit on what can be inferred or understood before writing any equation or using any specific technique.

- Try to complete the description and the solution of a circuit by solving for and showing all the information that can be gathered with respect to other parameters, currents or voltages, beyond the specific one or ones required by the text of the problem. Sometimes students get lost after solving the main step, because some links or details are not apparent to them; this phenomenon is probably one of the strongest confidence killers.

- Have students work solutions in groups, in class and outside. Circuit analysis is one of the disciplines where one can see contrasting approaches from different students. Anyone who has graded homework or exams in a circuits course can be a witness to that. This phenomenon can be used as an enhancement factor: students realize that other perspectives and/or approaches exist by interaction with each other. This can also serve as a correcting factor: a student proposing a wrong approach within a group will probably be challenged and proceed more correctly.

- Try to have proximity between lab activities or demonstrations and the theoretical/problem solving sessions in the class. Building, simulating, testing and measuring a circuit that has been studied analytically can act as a strong confidence builder, especially for individuals who reject abstraction and always look for real applications and solutions as the ultimate check of validity.

- Have individual sessions with individual students or small groups. Have them solve a problem and appreciate what their thought processes and approaches are. When needed, strengthen their technique within a correct approach and/or show alternative approaches when important or more efficient. (Difficult and very time-demanding to implement, but full of rewards in observing, over time, the confidence building and the enhancement of skills of some students.)

- Finally, let the students get your view of the course as a center stage towards achieving professional confidence that manifests itself in intuitive proficiency and natural depth of analysis. Students are always more motivated and cooperative when they understand the pedagogical goals and guidelines of the instructor.

Putting things into perspective

I have described above a number of specific techniques to engage a circuit class in a way that, presumably, facilitates the emergence of professional competence and confidence. It is nevertheless important to put things into a right perspective. In this regard some questions do naturally arise.

1) Is it reasonable to credit the formation of a well-rounded, confident graduating student, even partially, to these teaching and class engagement techniques? How much, for example, did the senior student in my initial daydream recollection really benefit from these specific techniques as compared to other components of his/her education?

2) Is the class as a whole better engaged when the instructor does use such techniques set to trigger and enhance the emergence of professional confidence towards the extreme of "circuit wizardry"?

3) Is there any way to assess, if not quantitatively at least qualitatively, a measure for both the emergence of professional confidence and the effectiveness of the techniques used to accomplish that?

The answer to those and other similar questions are complex and will not be exhausted in this single paper. It is evident that any added aspect or emphasis of a course is embedded in a background that includes the curriculum structure and its appropriateness, the general course setup and effectiveness, and the teacher pedagogic and communication skills. A good circuits course remains a good circuits course – as any other course, for that matter – independently if the teacher has thought and implemented the nuances towards emergence of professional confidence as described above in the paper. And a poorly taught circuits (or other) course would probably remains a poor course, independently of awareness and efforts to implement some of the strategies outlined above.

In another paper I did describe the sequence of circuit and electronics courses at the Department of Physics and Engineering at Elizabethtown College[1]. In that reference I did expand on the background, the curriculum, the approach and the strengths of the circuits/electronics courses. While I refer the reader to that work for specific details, I will just mention here how at Elizabethtown College the circuits courses are taught in a classroom-lab-studio setup enhanced by state of the art measurement equipment. It is within this general background that I have allowed myself to explore more subtle questions and goals in delivering circuits courses. Let me now revert to answering the questions raised above.

1) I think it is reasonable to credit the formation of a well-rounded, confident graduating student, at least partially, to these teaching and class engagement techniques. It is of course difficult to quantify the contributions of different ingredients to different outcome components in a student education. However, in the framework of the small-size classes at Elizabethtown College, the

strong emphasis on circuit and electronics classes allows us to individually follow our students' progress from course to course. Often the performance in the courses is matched by a strong performance in applied senior projects where circuit understanding and implementation are required. The circuit expertise and confidence acquired by the students is evident in most cases.

2) Using the techniques outlined in the previous section does help engage the class to enhanced participation and effectiveness. Some of these techniques are of universal appeal and some are geared specifically to a circuits course. The general theme and scope of the methods outlined is to try and take the class beyond a strict and formal attitude in analyzing and acquiring new knowledge towards a more agile, flexible and, ultimately, confident approach for developing proficiency and expertise in circuit analysis. The students are challenged by this approach and there is, on average, an obvious progress in the quality, speed and flexibility of their analyses and solutions as the course unfold and these techniques are implemented.

3) Beyond the standard student course evaluation forms, some assessment comes from information percolating from students who were enrolled in 3-2 programs at Elizabethtown College. Most of them stay in touch and report to us while completing two additional years at Penn State or some other engineering school. In the three years spent at Elizabethtown College most of them had taken at least one circuits class. Almost invariably, they all feel extremely well prepared for all advanced electronics classes at the new institution and they perform extremely well in those courses. The same can be said for our graduates who continue into graduate studies. As another avenue of assessment, I have recently created and started a personalized survey, which I elicit from the circuits class at the end of the course. In this survey I try to assess the students' views on how much the course contributed to change/expand their approach to problem-solving, and, more generally, to help integrating scientific or technical knowledge and to enhance professional confidence and expertise. While the class size was relatively small (12 students) in the first survey and the data-base is still too restricted to have any statistical significance, the first responses indicated that a majority of the students recognized the subtle contribution of the course techniques to problem solving skills and to professional expertise and confidence.

Having discussed all of the above, I want to emphasize that the main message in this work aims to be more general than a report on techniques and tools used in a circuit class with beneficial results. The more general signal is that future advancement in the effectiveness of pedagogic tools could come from a subtle, sophisticated approach to the courses we teach. We, the educators, should try to recognize what specific traits and skills are correlated to a particular course, or, better, what specific professional traits and skills can germinate or be enhanced within the unfolding of a particular course. I have used the concrete example of a course particularly familiar to me, a circuit course, to exemplify how these thoughts develop and are translated into implementation through practical teaching techniques and emphases.

Questions, additional questions

There are many more questions than need to be asked and addressed, but are beyond the scope of this paper.

Is there any way, beyond obvious course results and evaluations, or personalized surveys, to assess how effective are these efforts of facilitating the emergence of professional confidence and mastery in circuit techniques?

Are there any reasons to believe the emergence of such attributes with respect to circuit analysis proficiency does translate to an overall professional confidence expanded to other activities and topics?

Is this insight of opportunities to build and enhance professional confidence through circuits course techniques just a specific, confined phenomenon, relevant only to the nature of the discipline; or rather, concurrent, and maybe dominant, is there a transition in acquiring and tackling new knowledge in general, triggered by the emergence of advanced skills and enhanced confidence?

These and others are fascinating questions that will not be answered in this paper, but rather are left as food for thought for the reader.

Conclusions

I have tried to translate my curiosity and fascination from a juvenile appreciation of master circuit solvers and "wizards" into trying to analyze the skill and confidence building process in a circuit analysis class.
I have tried to review the interesting process in the perception of acquisition of knowledge and in the enhancement of skills, as it develops from basic science courses to circuits courses. I have tried to recognize the important factors in this process and to suggest techniques and tools to build and enhance desired skills and to induce professional confidence building in a circuit analysis course and through it.

References

[1] Ilan Gravé, **"**Integrated Course-Lab-Studio Environment for Circuits and Electronics Courses at Elizabethtown College," 2005 ASEE Annual Conference, paper #1662.

Biographical Information

ILAN GRAVÉ is an Associate Professor of Physics and Engineering. He joined Elizabethtown College in 2002, having previously taught at the University of Pittsburgh. His varied physics and engineering background includes research and industrial experience in Italy, Israel, and the USA.