
# Rethinking Electronics Fundamentals

Students need to get their hands on hardware from day one to truly translate theory to understanding. They need to not only learn the fundamentals, but also experience them by doing theory, design, and experimentation all at the same time. The University of Virginia (UVA) has partnered with NI to provide students with a hands-on, project-based approach to education that has resulted in negative attrition, vastly improved concept comprehension, and an increase in departmental national ranking by 16 positions.

NATIONAL INSTRUMENTS

## Challenge

UVA had been challenged by high attrition and low student engagement in its electrical engineering program. A team of professors decided that the program needed a complete change to the curriculum and teaching approach to attract the best engineering students and adequately prepare them for increasingly demanding careers in electrical engineering.

## Solution

These professors redesigned and rearranged the first three electrical engineering courses with the goal of helping students understand that what they learn in circuits, electronics, and signals and systems are really all part of a single problem in real-world engineering. The college of engineering partnered with NI to implement a solution that fit this new interconnected structure by giving students a hands-on experimental experience throughout every step.

## What Does a Student Need to Know?

In 2013, the electrical engineering department at UVA decided to address an ongoing problem with attrition and student retention through a comprehensive review of the program. Rather than looking at temporary fixes such as the addition of new classes or making shifts to the curriculum, we proposed a comprehensive review of the entire curriculum.

We began our assessment with one question: What would a student need to know when graduating? Two conclusions immediately surfaced after analyzing the professional engineer exam, working with alumni and employers, and surveying current students.

First, students needed more hands-on experience with circuits and measurement tools, which are ubiquitous in industry and research. Second, the electrical engineering department suffered from a lack of what our associate dean for undergraduate education, Dr. Lloyd Harriott, described as integration. Students would take course A, take the final exam, then hit the reset button in their mind before taking courses B and C. Students understood the topics in isolation, but not completely as a system.

Faculty concluded that students should handle hardware from day one to reinforce theory and build relevancy into their education through an increase in project-based learning. Students also needed to engage in


### Customer Profile

UVA was founded in 1819 and is a public research institution based in Charlottesville, Virginia. The School of Applied Science and Engineering has more than 2,695 undergraduate students with a focus of research in areas such as cyber-physical systems, neural engineering, and cyber security. The university includes a diverse population as 32 percent of students are female, compared to the national average of just 19 percent. The ongoing investment into the engineering program is a key reason why UVA continues to be ranked among the best public universities in the world by sources such as U.S. News & World Report.

their studies as a single process and use a common thread to connect each course to prepare them for real interconnected engineering problems. Students needed to experience the fundamentals of electrical engineering by learning the theory, implementing it through design, and analyzing through experimentation all at the same time.

**↑ 15%**
increase in concept inventory pass rate

## Redesigning the Engineering Curriculum

The partnership between NI and UVA began in 2013. We explored how we could take advantage of NI technology and its capabilities to build a vision around a studio learning approach focused on design and experimentation. To drive consistency, we examined the first three courses in electrical engineering together as if they were a single electrical engineering course. We wanted to show students that what they learned in different courses were connected and part of the same whole. We took the first three required courses: circuits, electronics, and signals and systems, and built components of each into three consecutive Fundamentals courses. Now, when we talk about filters and Fourier analysis, we present these subjects together rather than studying separately as just a mathematical concept. The goal is for each student to understand when and how to use concepts in the real world.

Redesigning the courses required students to do exercises that they would complete as they progressed through the three integrated courses. We built the student journey on simulating electronics, defining a physical printed circuit board (PCB), and then testing performance through instrumentation.

ELECTRONICS FUNDAMENTALS

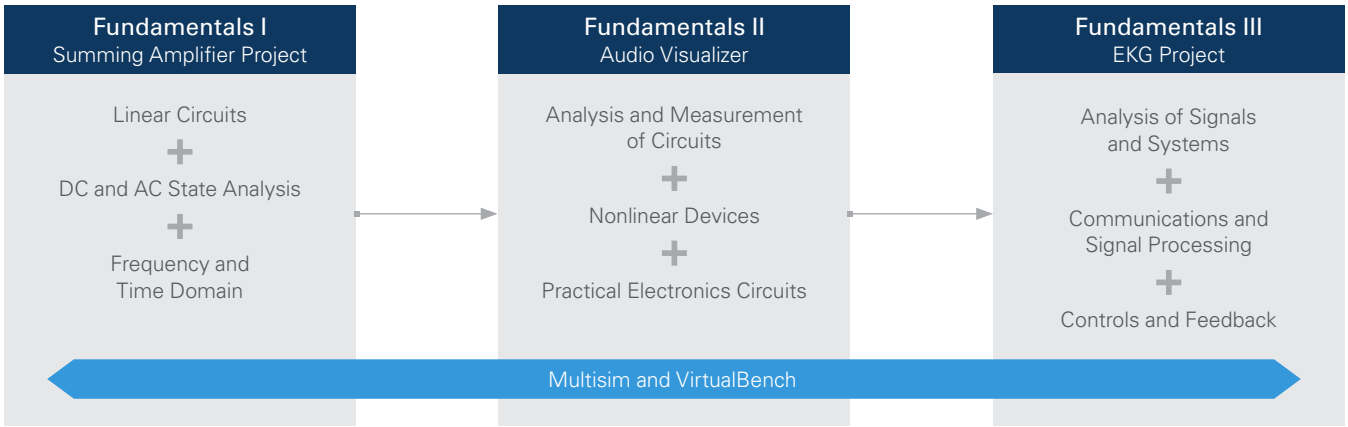



Figure 1. Progression of topics through the three fundamentals courses.

In partnership with NI, the department integrated SPICE simulation through the Multisim circuit teaching environment and instrumentation through the VirtualBench all-in-one instrument. Students could take advantage of this combination to simulate, prototype, layout, and validate their designs over the course of a single semester.

In building the program, we made sure that students see and learn about the final project on the first day. Students need to understand that as they complete an experiment, they are building knowledge to eventually help complete the final project. In the first course, Fundamentals 1 (FUN1), the students go through the full design process to create a summing amplifier. They lay out a PCB with Multisim, print it, solder on components, and validate with VirtualBench.

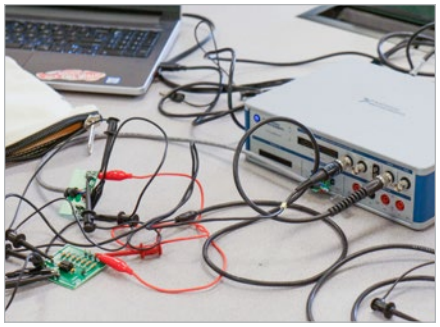


Figure 2. Students in FUN1 test their summing amplifier circuits using VirtualBench.

In the current third course, FUN3, students build an EKG amplifier as a part of a larger system. The increasing level of difficulty challenges students to start thinking about board layout issues and feedback systems. The final output of the design connects to the NI myRIO student embedded controller for digital signal processing. We find that measuring real signals, like their own heartbeat, is an incredibly memorable event for students. It stays with them.

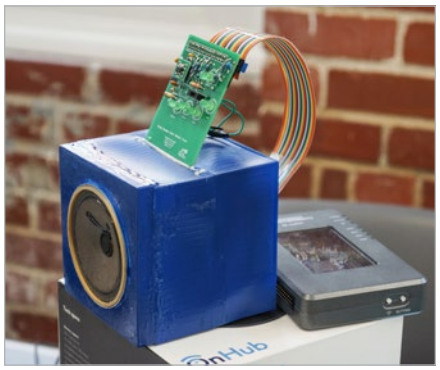


Figure 3. A capstone design project utilizing myRIO to control a stock-ticker.

## Results

The class of 2017 was the first to go through the new program. At this milestone, we could clearly see the impact of this new curriculum design. We tested concept retention one year after FUN3 with a concept inventory to measure what students took from the course. The class of 2017 saw a 15 percent increase in the concept inventory pass rate compared to the previous year.

Involving students directly in hands-on experimentation has had a positive effect on retention. In a recent survey, 91 percent of students who have taken a Fundamentals course feel that hands-on activity helped them understand the concepts more deeply, and 84 percent of students thought doing the lab during the class helped clarify their understanding of the concepts.

The key metric that UVA has continued to track since 2013 is student attrition. With the new program focusing much more on student engagement and hands-on learning, the electrical engineering department now has negative attrition. The department ended the semester with more students than it began with.

The largest anecdotal changes can be seen in the capstone design course. The capstone class itself has not seen a structural change, but the students and student projects have seen significant improvement. This year, with the background in the Embedded and Fundamentals courses, the projects have become ever more elaborate, complex, and sophisticated (Figure 3).

## Next Steps

In the past four years, UVA has focused significant resources on improving the quality of its undergraduate and graduate electrical engineering programs. The concerted efforts of the faculty to not only look to advanced research, but also completely overhaul the undergraduate program with a curriculum change, helped the department national ranking increase by 16 positions as of 2017, an impressive testament to the faculty.

The implementation of the Fundamentals courses and the curriculum redesign have been tremendously successful. We estimate that the electrical engineering curriculum is about 75 percent hands-on, but we hope to make curriculum 100 percent hands-on in the future.

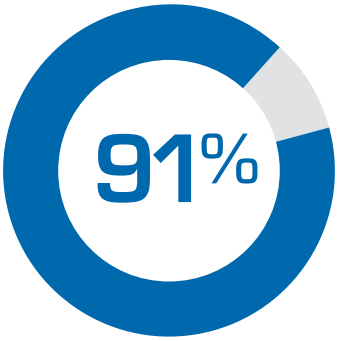
We are keenly interested in working with other universities on curriculum and influencing other university curriculum reform. Sharing information helps electrical engineering departments grow, which is why UVA has made the FUN1 labs available online for anyone to download at ni.com/teach/ece-fun1.

Dr. Harry Powell,
Associate Professor and Associate Chair of Undergraduate Programs,
University of Virginia

the EE department has advanced

**↑16**

positions in national ranking




of UVA students said hands-on learning helped them understand concepts

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## NI Products

- VirtualBench
- Multisim
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Access the Fundamentals I labs at **ni.com/teach/ece-fun1**