UPENDING THE LECTURE

HOW ONLINE TEACHING METHODS ARE ENHANCING ON-CAMPUS LEARNING

BY MARK DWORTZAN

PHOTOGRAPHS BY CONOR DOHERTY

Guided by the instructor and learning assistants, EK127 students spend class time solving problems.

At the front of one classroom in the Photonics Center, instead of a lecturer or PowerPoint presentation there's just an old-school wall clock whose hands sweep out 120 minutes while students essentially conduct the class from their seats.

Collaborating with their peers at 10 clusters of rectangular tables in this well-lit, oblong "learning studio," and guided by Assistant Professor Stormy Attaway (ME) and three learning assistants (specially trained undergraduate teaching assistants), 75 students in EK127: Introduction to Engineering Computation solve computer programming problems that apply concepts from online course videos that they viewed from the comfort of their dorm rooms and apartments. Some problems are chosen based on common trouble spots pinpointed via mandatory quizzes that accompanied the videos. Students share their work on whiteboard-painted walls (slated to be replaced by electronic whiteboards by Fall 2015) and with Attaway and her learning assistants, who dart from table to table throughout the two-hour class.

"I'm constantly roaming around the room," says Attaway, who has spent most of her academic career standing in front of amphitheater-style lecture halls, directing her remarks at the average student rather than tailoring them for individual students. "I'm now talking to every student multiple times per class, and student engagement is through the roof."

Welcome to the flipped classroom, College of Engineering-style. Rather than delivering a lecture to row after row of students dutifully taking notes, with little or no interaction between lecturer and note-takers, and then assigning problem sets for students to solve at home—the model for science and engineering for more than a century—Attaway is leveraging leading-edge digital learning technologies to essentially do the opposite. So far she's found the approach has paid off, yielding substantial improvements in student engagement, understanding and performance.

EK127 blends the best of the virtual world—state-of-the-art web hosting and video production technology from edX, a nonprofit online platform offering Massive Open Online Courses (MOOCs) from Boston University and other member institutions—and the residential classroom, where dedicated faculty and teaching assistants guide students through the problem-solving process. The goal is to enhance the quality and value of the undergraduate engineering learning experience on campus.

"Blended learning" experiments like this one are revolutionizing engineering education, and Boston University, which launched its Digital Learning Initiative (DLI) in 2013 to spearhead innovative projects in online learning at all of its schools and colleges, is fully on board. Last year the DLI awarded $80,000 to fund a College of Engineering proposal to enhance EK127 and another core undergraduate engineering course, EK307: Electric Circuits, with a suite of online technologies and techniques. In both courses, instructors and teaching assistants funded by the DLI grant have developed online content not as a vehicle, like MOOCs, to reach large numbers of students via the Internet, but rather as a tool to free up precious time to focus on the application of knowledge in the classroom.

Professor Thomas Little (ECE, SE), the College of Engineering's associate dean for Educational Initiatives, sees these and other ongoing pilot projects as part of a broader College-wide effort to combine the most effective active learning techniques with the latest digital learning technologies—from tablets to MOOCs—to bring engineering education into the 21st century.

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"Inspired by the success of these technologies in other disciplines and energized by the support and training DLI is providing, we are developing new ways to improve what's important to the student: learning, retention and career preparation," says Little, who heads a team of seven ENG faculty members spearheading digital learning innovations at the College.

Little walks his talk. After teaching EC/ME/SE 544: Networking the Physical World the conventional way for five years, he flipped it two years ago, replacing lectures with active learning modules and hands-on challenges that develop and apply concepts assigned as preparatory exercises. The course is comprised of eight challenges of increasing complexity, leading to the demonstration of self-driving cars that navigate the fourth floor of the Photonics Center using wireless communications and indoor positioning technology.

"Restructuring the course in a blended learning format has enabled students to have more time in class to solve problems and develop working systems that demonstrate their command of the theory," he says.

In effect, Little, Attaway, Horenstein and other innovative ENG faculty are reengineering their courses so that their students can spend more time practicing engineering.

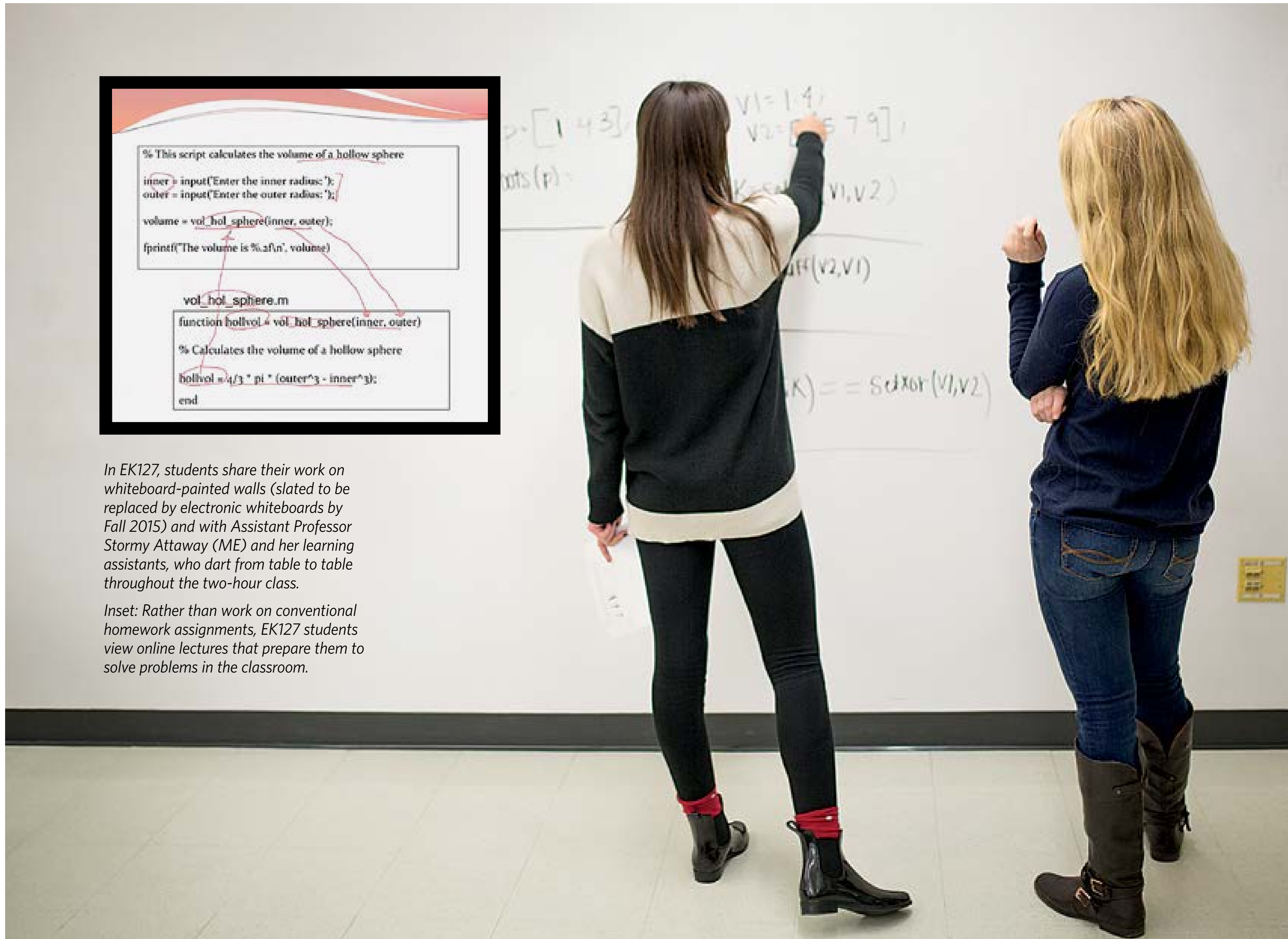
EK127: STORMY ATTAWAY

EK127: REPLACING PASSIVE LEARNING WITH PROBLEM SOLVING

Attaway, who in 2014 received the Metcalf Cup and Prize, Boston University's top teaching honor, has been gradually flipping the course over the last three years. Supported by DLI funding, she produced course videos using Camtasia as the screen capture technology, and, thanks to "course builder" Declan Bowman (BME'15)—one of the first students in the College's STEM Educator-Engineer Program (STEEP)—posted them on the webhosting platform edX edge. With all course content (documents with goals for each class meeting, short videos and questions to assess student understanding of the material) placed online, class time is now exclusively reserved for active learning in Photonics Room 117.

In the spring of 2014, Attaway began flipping the course in its usual amphitheater-style classroom, testing out the approach in one of the course's three sections.

A student in the experimental section, Lauren Etter (ME'17), found that the combination of online lectures and active learning in →



In EK127, students share their work on whiteboard-painted walls (slated to be replaced by electronic whiteboards by Fall 2015) and with Assistant Professor Stormy Attaway (ME) and her learning assistants, who dart from table to table throughout the two-hour class.

Inset: Rather than work on conventional homework assignments, EK127 students view online lectures that prepare them to solve problems in the classroom.

the classroom enabled her to grasp the course material much more effectively than the traditional method.

"When studying for a quiz or exam, it was easy to go back to the videos and refresh what I had learned without having to rely on notes, which may not have been entirely correct. In addition, working with other people in the classroom helped me to learn the material more thoroughly. For example, when I was struggling to understand graphical user interfaces, the other students in my group helped clear up my misunderstandings, and when all three of us got stuck, the learning assistant was there to help us."

Continuing her experiment into the summer, Attaway invited a class of 23 EK127 students to go online and view the first course module (four to five approximately seven-minute lecture videos, primarily consisting of PowerPoint slides with a voice-over by Attaway) before coming to the first class meeting. Once in the classroom, students gathered at small round tables and worked on three or four assigned problems, first as individuals and then in groups of three as a graduate teaching fellow and several teaching assistants milled about, explaining with groups as necessary to explain concepts ranging from data structures to numerical methods.

"The students were actively engaged from the beginning," says Attaway. "The peer-to-peer instruction worked very well. On a scale of 1 to 5, with 1 being "not at all" and 5 being "very," the average response on how much the group in-class exercises enabled them to learn was 4.5. Of the 23 students, 16 earned grades in the A range, 6 in the B range and one in the C range, and there were no D, F, or W grades. In my opinion, the class was a smashing success."

Building on that success and adding more learning materials for the course site on edX edge, Attaway has now delivered essentially the same experience to her 225-strong Fall 2014 class (three sections of approximately 75 students each) in the new, more flexible Photonics 117 studio space. Compared to the Spring 2014 class, where only one-third of the students learned in a partially flipped classroom, the average grade point average rose from 2.9 to 3.6, and average attendance increased from 89.8 to 95.2 percent.

Chris Mullen (ME, MS'15), who has served as a learning assistant for EK127 for the past three semesters, has seen a dramatic improvement in class preparedness since Attaway started flipping the course.

"In previous semesters, students would be required to complete a reading assignment before coming to lecture, and then lectures would present material covered by the reading. By halfway through the semester, most students would decide that they could get away without doing the reading and just listen to lecture, so instead of having the lecture to ask questions and clarify their understanding of the material, they were hearing everything for the first time. Because the students are now watching the videos and getting the 'lecture' before class time, they have time to figure out what they don't know, and what to ask."

EK307 AND EK210: FREEING UP TIME FOR HANDS-ON ENGINEERING

Supported by DLI funding, Professor Mark Horenstein (ECE) has developed a series of 30-minute course modules on circuit analysis and design to prepare EK307 students for the course's weekly lab. Always available to students and consisting of animated, voice-over PowerPoint lectures and lab demonstrations produced with Camtasia and uploaded to a video hosting service, the modules function as tutorials that present essential concepts and practical information to help students get the most out of each lab.

In the course, students design and construct circuits and test their results in the ECE Department circuits and electronics teaching facility. Aside from a basic introduction they get in their physics classes, this is the first course in which they are immersed in the details of circuit design, and the amount of material they're expected to absorb can be daunting. The lab videos help students to master often-complex concepts, illustrating them with images, diagrams and schematics.

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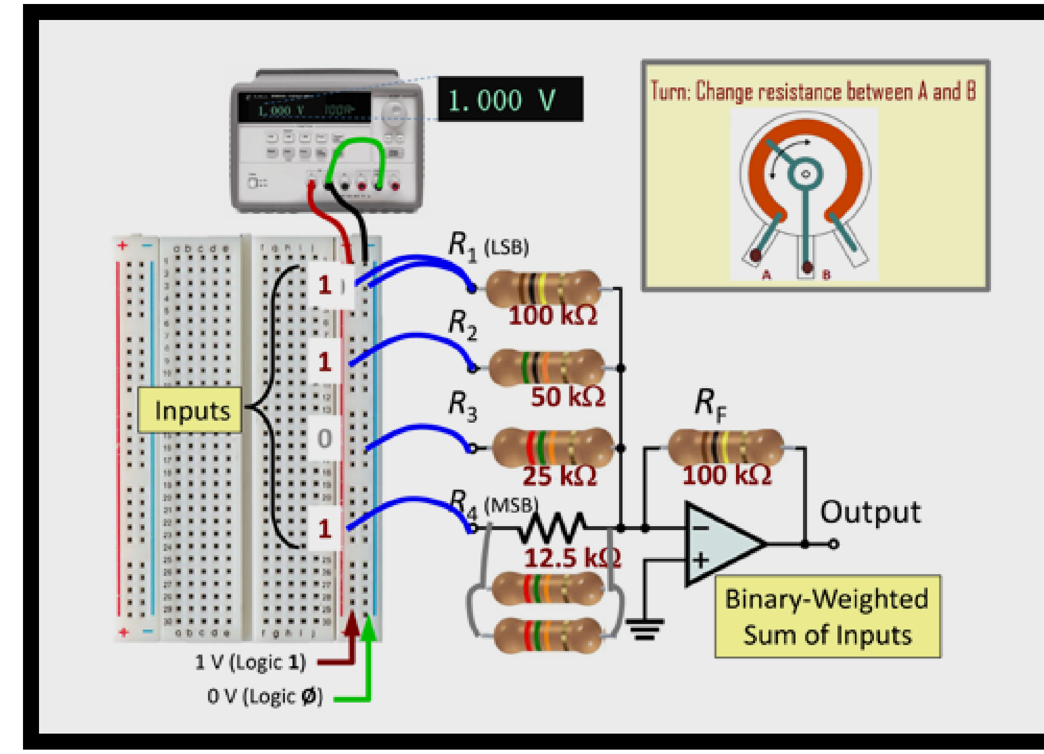
"Mark's videos have been a hit with our students," says Aleks Zosuls, the course's lab instructor. "Even without Mark physically in the lab, his voice emanates from speakers and headphones as students use the videos in a self-paced manner to help them with their lab work. It's like having a personal TA over your shoulder while working, with the added benefit that you can pause the video while you digest an aspect of the material."

"The videos have been helpful in giving you an overview of what your circuits might look like before you get to the lab," says EK307 student Fritz Jolivain (EE'17). "They've helped me feel more confident in translating a circuit to a breadboard to see how it works."

Another College of Engineering course using videos to prepare students for hands-on engineering is EK210: Introduction to Engineering Design, a two-credit class aimed at giving sophomores a basic understanding of how to develop a product from concept through design and deployment. Meeting in the Engineering Product Innovation Center's (EPIC) Lorraine A. Tegan Design Studio, students work in multidisciplinary teams with time and budget constraints on externally sponsored design projects. By viewing web-based lectures at home on topics concurrent with specific phases of the projects rather than receiving this information via in-class lectures, students are able to devote most of their class time to working on their projects in the design studio.

"We're trying to teach students hands-on engineering design, but we only have them two hours a week," says EK210 instructor and →

Prepped and guided by an online course video, EK307 students use an oscilloscope, volt meter and other lab equipment to compare the input and output of a circuit.



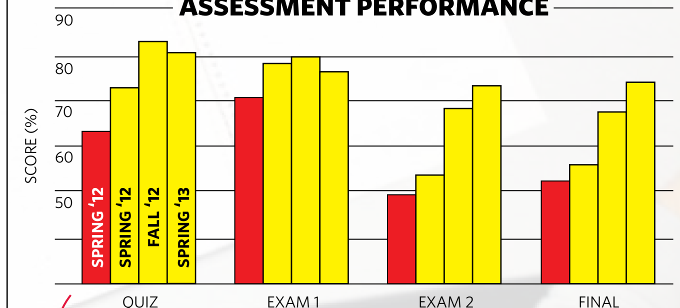
In this in-class problem presented in EK301, students analyze forces acting on a horizontal beam and enter their work on iPads. Their solutions are wirelessly uploaded to the file-sharing service Dropbox.

Lecturer Caleb Farny (ME) has dramatically increased active learning in the classroom without producing videos or redesigning the lecture hall, both of which can be expensive and time-consuming. His approach enables immediate access to digital learning technology when studio learning space is not available.

THE PROOF IS IN THE GRADING

In a study that Lecturer Caleb Farny (ME) and Associate Professor Sean Andersson (ME) presented to the American Society for Engineering Education in 2013 comparing EK301 mean quiz and exam scores for classes using the traditional approach with those enhanced by active learning, they found that students achieved significantly higher scores with the new active learning format, regardless of grade point average.

ASSESSMENT PERFORMANCE



The figure shows comparison of mean scores per assignment based on section. The quiz scores were the mean of the nine quizzes given throughout the semester, and the multiple sections for the Fall 2012 and Spring 2013 sections were each pooled together.

WHAT DOES IT ALL MEAN?

The performance in the sections with an active learning format was higher for all assignments and semesters.

Professor of the Practice Gerry Fine (ME), who directs EPIC. "When we started working on the course we assembled an ad hoc committee and quickly came to the realization that flipping the classroom was the best way to solve the problem."

Produced using Echo 360 and hosted by BlackBoard Learn, each online module contains about an hour of required video material consisting of five to six segments of about 10–12 minutes each delivered by Fine, other ENG faculty or sourced externally, and one or two brief quizzes to ensure the material is understood. Students then implement what they learned in the Tegan Design Studio while Fine and his teaching assistants roam the room to respond to individual and team questions as they arise.

Hannah Zengerle (ME'17) found the online videos useful in covering topics that didn't get addressed in class.

"For our first project involving reverse engineering, the presentation itself was about half of the grade," Zengerle recalls. "One of the videos showed exactly what to include in the presentation as well as how to present it, and answered questions I had not had time to ask in class."

For Alexander Moyse (ENG'17), the videos' principal advantage is their accessibility.

"Unlike in most classes, I can watch the video as much as I want, whenever I want, until I understand all of it," he says.

EK301: ENERGIZING THE CLASSROOM WITH IPADS

The two DLI pilot projects, EK127 and EK307, leverage pioneering work by faculty members in the Physics Department, including Professor Bennett Goldberg (Physics, ECE, BME), in peer-based learning and the use of studio space. The projects also apply lessons learned in ongoing, digital technology-enabled, classroom-flipping efforts by Fine in EK210, Assistant Professor Martin Steffen (BME, MED) in BE 209: Principles of Molecular Cell Biology and Biotechnology, and Lecturer Caleb Farny (ME) in EK301: Engineering Mechanics.

As the College's team of digital learning enthusiasts expands the use of blended learning technologies and techniques on campus, it also recognizes that one size does not fit all.

With funding from a BU Redesigning the Undergraduate Learning Experience (RULE) grant, Farny has shown that one can dramatically boost active learning in the classroom without having to produce videos or redesign the physical space. Since the Spring 2012 semester edition of this required engineering course intended for sophomores, much of the lecture has been replaced by interactive problem-solving sessions and class discussions, all in a conventional lecture hall.

Twice during each 110-minute class meeting, the instructor presents a 15-minute overview of a new concept and students work in groups of four on an example problem. Over 15 minutes, each group uses an iPad and stylus to show each step of its solution—including diagrams that depict the forces acting on a structure—and wirelessly uploads it to the file-sharing service Dropbox, where it may be accessed after class. Meanwhile, the instructor and three graduate teaching fellows and learning assistants circulate about the room to answer questions. When time is up, the instructor projects selected work on an overhead screen and invites a representative of the group to show how it solved the problem, using its iPad entries to highlight correct steps and common errors.

Class discussions of student solutions are strictly focused on helping students to become better problem solvers, says Rebecca Rucks (ME'16), an EK301 learning assistant and former student of the course. "There's no judgment when something is done incorrectly. It's all seen as a learning experience."

Farny evaluated the new approach to EK301 the first semester it was introduced, offering one section in the old format and a second section in the new, but keeping all quizzes and exams the same. In a study that he and Associate Professor Sean Andersson (ME) presented to the American Society for Engineering Education in 2013 comparing mean quiz and exam scores, they found that students achieved significantly higher scores with the new format, regardless of grade point average.

"This showed that our new, active learning approach worked well, and it's been the format of the course ever since, unifying the course across multiple sections and improving test scores," says Farny, who seniors voted Mechanical Engineering Professor of the Year for 2012.

Higher test scores stem from improved engagement with and understanding of the course material, observes Pantelis Gkaliamoutsas (ME/Economics'15), a learning assistant for EK301.

"In a group format like the one in EK301, students are free to ask questions amongst themselves or call on a learning assistant or graduate teaching fellow for help," he says. "This is important since many students feel more comfortable talking to the assistants rather than to the professor. I realized from my experience as a student in EK301 that I understood the problems we did in class more thoroughly, and was thus able to perform better on exams and quizzes."

Inspired by the success of EK301, Farny started flipping a senior-level course, ME 310: Instrumentation and Theory of Experiments, in the Fall 2014 semester, replacing ten hours of lecture with 18 course videos on the edX edge platform for home viewing and in-class measurement exercises in which student groups use plug-in sensors and portable data acquisition devices to conduct experiments and share their results onscreen.

GOING DIGITAL, AMONG OTHER THINGS

While digital learning has been a resounding success in courses that have tried it, the method is only beginning to gain traction at the College of Engineering.

"At this point there is ample evidence that flipped classes with active learning environments work; the focus is now on how to get faculty to adopt these best practices," says Attaway, noting that transforming a traditional lecture into an online course module—breaking it into bite-sized chunks, recording the video and hosting it on the edX platform—can take up to 20 hours. Simply letting go of the familiar lecture format can be challenging for some faculty. "Although my primary goal is to improve the learning experience for my students, my secondary goal is to be a resource for my colleagues so that I can help them transform their courses."

Toward that end, a College of Engineering faculty committee on digital learning initiatives is sharing best practices among faculty, redesigning courses (including ongoing efforts to flip EK127 and EK307), and purchasing new digital learning technologies, from electronic clickers that students can use to relay instant responses to questions posed during a lecture, to large, overhead projection screens to display solutions uploaded from student groups at active learning tables.

As the College's team of digital learning enthusiasts expands the use of blended learning technologies and techniques on campus, it also recognizes that one size does not fit all.

"In my experience, students learn in myriad ways," says Horenstein. "Some students thrive in the traditional lecture/homework environment, while others learn best in a hands-on setting, for example, when a small group works with a professor during office hours on specific problems and concepts. Still other students learn best in the laboratory, where they can transfer lecture/discussion concepts into the hands-on design of electric circuits that solve a problem or meet a desired specification. The hope is that digital learning will service all of these learning styles and more." ■