Undergraduate Thesis Research
CREATING THE TEMPLATE FOR UNDERGRADUATE RESEARCH

For all undergraduates at the U.Va. Engineering School, the undergraduate thesis looms large, not only because of its scope but also because it is a personal expression of their own curiosity. The challenge we offer our students is to take a question that engages them, acquire the knowledge through reading and experimentation needed to address it and write a clear and compelling account of their findings.

Seen in this light, the undergraduate thesis is a critical step in their intellectual development. Jointly guided by faculty from their technical discipline and from our Department of Science, Technology and Society, students learn to take the initiative, work independently, think creatively and apply the skills we have taught them to tackle a problem that is meaningful to them.

Increasingly, our students base their undergraduate theses on research projects they are conducting in faculty laboratories or on their own, often supported by funding from the University’s Harrison Award program or by Engineering School donors. As you will read in this issue, these projects are varied and fascinating. They range from helping to create biofuels from algae to perfecting biomimetic heart cells that ultimately could be used to supplement damaged tissue.

An important goal of our schoolwide strategic planning process, currently under way, is to expand and strengthen undergraduate research. This entails, for instance, finding additional space to dedicate to their projects and creating a framework for faculty to advise and mentor students more efficiently.

Our resolution of these issues is of vital interest to the University of Virginia as a whole. It is turning to the Engineering School for leadership as it works to increase the quality and number of research opportunities available to undergraduates. In essence, the University plans to make the educational experience at all U.Va. schools more like the one we’ve offered our students since William M. Thornton established the thesis requirement in 1904.

Ed Berger
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A NEW MODEL FOR ENGINEERING EDUCATION

“In all these programs, students tackle problems that really need a solution. It’s a test not only of what students know but also of their creativity and commitment.”

Over the last decade, the undergraduate experience at the Engineering School has changed dramatically. From their first year, students are now involved in open-ended engineering design projects, often collaborating with students from other schools at the University. They are encouraged to launch their own research projects and to apply their engineering skills to helping people overseas develop basic services like clean water and electricity. Much of the credit for this change goes to Professor Paxton Marshall.

QUESTIONING OLD ASSUMPTIONS

For many years, Marshall, former dean of undergraduate programs and a faculty member in the Charles L. Brown Department of Electrical and Computer Engineering, had a nagging sense that the traditional model of engineering education was not preparing students for the world that awaited them after college. This feeling was validated during the 1980s and 1990s, when organizations like the National Academy of Engineering issued a stream of reports that stressed the importance of teaching engineers the skills they would need as practicing engineers: the ability to design and conduct investigations, analyze and interpret data, work in teams and communicate effectively.

BUILDING BRIDGES ACROSS DISCIPLINES

Marshall responded to this challenge by developing a number of interdisciplinary projects for his students that he felt more closely approximated real-world engineering. A decade ago, he began collaborating with John Quale, an associate professor of architecture who is interested in affordable, sustainable housing. Students in their classes worked together to build a house for the U.S. Department of Energy Solar Decathlon as well as a series of ecoMOD homes for families in Charlottesville. “I found that what I was looking for was the opportunity to engage students in a real project,” Marshall says. “If you are trying to design a working renewable energy system, you have to learn what you need to do to accomplish that goal.”

FINDING OPPORTUNITIES FOR ACTIVE ENGINEERING

Over time, Marshall has refined his approach. His project-driven courses are more structured than they once were. His students now work in teams rather than as individuals and typically collaborate with community groups. At the same time, he has explored this experiential approach to education in a variety of settings. He offered a University Seminar for first-year students called Designing a Sustainable Future and joined with other Engineering School faculty in reconceptualizing Introduction to Engineering as a design course. He has also been active in interdisciplinary courses, partnering with Architecture School professor Phoebe Crisman and Commerce School professor Mark White to develop Global Sustainability, a popular lecture course. With Environmental Sciences professor Bob Swap he offers Engineering in Community Settings for students engaging in projects overseas.

“In all these programs, students tackle problems that really need a solution,” he says. “It’s a test not only of what students know but also of their creativity and commitment.”

Throughout his career, Professor Paxton Marshall has been a leading advocate of hands-on, interdisciplinary research projects for undergraduates.
Michael Booth (CS ’11) is tired of compromising with his computer. His programming software sometimes forces him to use his mouse when it would be more convenient to use the keyboard. “It’s distracting,” he says. “I wanted to figure out how to improve my productivity, and it struck me that using my eye gaze to control my computer would be one answer.”

Working with Mary Lou Soffa, the Owen R. Cheatham Professor of Computer Science and department chair, Booth is applying his eye-gaze insight to a security notification system that she is developing for cell phones. For instance, when a cell phone’s GPS indicates that users have entered a dangerous neighborhood, a warning message would appear on their screen.

Not all users might respond to a warning like this in the same way. People who live in the neighborhood might just scan the headline, but not see any significant cause for alarm, while strangers might read the entire notification carefully and choose a safer destination.

Booth is writing a program that would establish their preferences for notifications simply by tracking users’ eye gaze. “People who read the entire notification in certain situations, whose eyes move down the screen, would continue to get complete notifications in those situations,” he says. “Those who quickly glance at just the heading would just get brief alerts.” The eye-gaze data could be collected by a simple webcam or camera built into the cell phone.

The toolkit Booth is producing could be adapted for other kinds of information, like news feeds, as well as to enable the user interface to anticipate user preferences. “In essence, the cell phone learns your responses without your having to teach it,” he says. “The program is a way of making cell phones and ultimately computers seem just a little smarter.”
In his research, Pritom Das subjects samples of a blast-resistant magnesium alloy to heat and deformation.

**LIGHTWEIGHT ARMOR**

The U.S. Army is investigating the use of blast-resistant magnesium alloys like WE43 for the next generation of ultralightweight metallic armor. Pritom Das (Engr Sci ’11), an engineering science major, is working with Sean Agnew, an associate professor of materials science and engineering, to determine the ideal processing conditions for WE43. He subjects samples to deformation at different temperatures and determines their ductility. He then characterizes the samples using various devices, from optical microscopes to scanning electron microscopes. “We want to determine what kinds of heating and deformation will lead to undesirable changes in the structure of WE43 so that these conditions can be avoided during processing,” he says. His findings will form the basis of his undergraduate thesis.

Although Das plans to go on to medical school, his experience in the laboratory has helped him narrow his career choices. WE43 has the potential for use in medical implants, and his work with the alloy has led Das to an interest in orthopaedics. He is also interested in going to a medical school with an active research program. “It’s exciting being exposed to cutting-edge techniques and being involved in a project that is both innovative and has real-world applications,” he says.

**SEQUESTERING CARBON DIOXIDE**

Coal powers America—and that’s both a blessing and a curse. The United States produces almost 50 percent of its electricity at coal-powered plants. With more reserves of recoverable coal than any other country, it is likely that it will continue to do so for many decades to come. At the same time, coal is the single biggest source of the country’s pollution. In an average year, a typical coal plant generates 3.7 billion tons of carbon dioxide, the primary source of global warming.

A solution being explored by the federal government is carbon capture and storage, essentially trapping the carbon dioxide in a power plant’s exhaust gases, compressing it and piping it underground, perhaps in deep saline aquifers. Working with Andres Clarens, an assistant professor of civil and environmental engineering, Jasmine Copeland (CE ’11) is focusing on how carbon dioxide will react with clay in the rock of these aquifers. They bubble carbon dioxide into a chamber filled with a briny solution and lined with rock. She then captures images of the bubbles coming in contact with the rock. By measuring the contact angle, she can infer facts about the interaction.

“To do research, you really have to educate yourself,” she says. “You have to keep up with the latest developments in the field and go beyond what you learn in class.”
Sometimes it pays just to ask. A work-study student in the Department of Mechanical and Aerospace Engineering, Lynna Nguyen (CE’11), asked Professor Pamela Norris if she knew of any research she could do instead of filing. Norris connected Nguyen with Donald Jordan, a senior scientist in the department, and graduate student Christina Haden. They are part of a team building a biomimetic heart cell, a device made from electro-active polymers that mimics the basic characteristics of a biological heart cell. The device will operate by controlling and sensing the transport of ions, much as its biological counterpart does.

Nguyen’s role is to create a sensor that will be embedded in the device to determine the location and concentration of potassium ions. This is a crucial part of the project because potassium ion flows regulate the cell’s contraction. She is replicating a recently developed sensor and characterizing its response to different potassium levels. “I never thought research would be so interesting,” she says. “Don and Christina give me a lot of independence, but I always feel I can talk to them when I get stuck.”

The ultimate goal of the project is to produce operational biomimetic heart cells, scale them down in size as far as possible and then create artificial cardiac tissues by connecting large numbers of them together. Such tissues could be used to investigate heart disease or form the basis of a new class of biomimetic fluid pumps.
The experience of Matthew Aronson (ChE ’11) highlights the value of the Engineering School’s policy of encouraging undergraduate research. At the beginning of his second year, he approached Robert Davis, chair of the Department of Chemical Engineering and the Earnest Jackson Oglesby Professor, about doing research in his laboratory. Davis agreed and assigned him to help graduate student Joseph Kozlowski on his research project. “I thought it would be a great way to supplement what I was learning in the classroom,” Aronson says.

Aronson presented his project with Kozlowski at the ACC Meeting of the Minds, a showcase for undergraduate research, and with mentoring from Davis and Kozlowski, secured a summer internship with ExxonMobil. In the process, he developed the knowledge and laboratory skills to launch his own independent research project in his third year, trying to develop a better catalyst to convert lipids produced by algae into biodiesel fuel. He is trying to synthesize a solid, noncorrosive, recyclable version of the catalyst currently used for the process, characterize it and conduct reactivity studies to determine its effectiveness.

This work in turn enabled him to spend last summer in Berlin at the Fritz Haber Institute, analyzing his catalyst using advanced characterization techniques. Taken together, all of his research activities played a role in Aronson receiving a Goldwater Scholarship, making him one of just 300 students nationwide to receive this prestigious award. “Research has given me the opportunity to think independently and apply my knowledge,” he says. “More than that, it has opened doors for me that never would have opened otherwise.”

Goldwater Scholar Matthew Aronson credits his experience as an undergraduate researcher for his success in winning this prestigious award.
The undergraduate career of Beth Martin (Aero ’10) shows that insignificant events can sometimes have outsized consequences. As a second-year aerospace engineering major, she overheard friends discussing the Hy-V Scramjet Project being conducted at the Engineering School’s Aerospace Research Laboratory (ARL). Intrigued, she followed up by e-mail with the lab’s director, Research Assistant Professor Christopher Goyne—and today she is a graduate student in Stanford’s Department of Mechanical Engineering.

“I joined the Hy-V program out of a sense of curiosity, not because I knew I wanted to become a researcher,” Martin recalls. “But I soon was hooked by the problem-solving aspect of doing research.”

A scramjet is an engine that can attain speeds as high as Mach 5, or five times the speed of sound, when launched from a rocket or conventional jet plane. The Engineering School’s hypersonic wind tunnel is the only one of its kind in the country that can simulate Mach 5 conditions for several hours at a time. For her undergraduate thesis, Martin worked with a team developing a new way of quantifying the combustion efficiency of a scramjet in the wind tunnel by combining spectroscopy and computed tomography. Together, they produce detailed, two-dimensional images across the plane of the flow. The International Journal of Hypersonics recently accepted an article based on her findings.

Martin points to the research she did at the ARL as one reason she was successful in applying to graduate school. At Stanford, Martin is focusing on developing BioMEMS, microelectromechanical systems for biological analysis. Currently she is working on research aimed at measuring mechanical forces exerted at the single-cell level to determine how cellular mechanotransduction affects internal signaling pathways.