Students Using Nanotechnology to Solve the World's Greatest Challenges

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Scientia

STUDENTS USING NANOTECHNOLOGY TO SOLVE THE WORLD'S GREATEST CHALLENGES

The field of engineering is central to innovations across science and technology, yet many college students show a lack of interest in pursuing engineering careers. Educators at Auburn University are developing innovative educational modules that engage students in solving humanity's biggest challenges using cutting-edge engineering techniques, cultivating enthusiasm for engineering careers along the way.

From climate change to clean water, and from life-saving pharmaceuticals to international security, many of the present challenges facing humanity can only be solved through science and engineering. As technology has advanced over the past century, the field of engineering has found itself at the crux of modern science, touching every scientific discipline from biology to astrophysics.

Through the creation of advanced materials and incredible leaps in computing, engineers shape the human experience in countless profound ways. Our future will depend on engineering innovations in every corner of science and technology. Despite the need for diverse and talented engineers, first-year college students report low interest in pursuing engineering as a major, and many of those that do take engineering courses in their first year will not continue on to achieve engineering degrees.

Thus, while the world relies on engineers to solve major challenges, one of the biggest challenges within the field is increasing the number of young engineers. Further, the male-dominated field stands to benefit from the unique perspectives offered by female engineers and under-represented minorities, yet retaining these demographics has proven difficult in standard educational models.

Now, a team of researchers at Auburn University have developed a set of educational modules for first year engineering students to help enhance the freshman learning experience and alter perspectives about what it means to be an engineer. Drs Edward Davis, Virginia Davis, and Joni Lakin are determined to reshape the way students engage with engineering at the beginning of their careers, in the hope of retaining broader diversity and student involvement.

Dr Edward Davis describes the team's drive: 'The future will be shaped by the things engineers develop – new power sources, better and cheaper medicines, new diagnostic equipment to catch diseases earlier, new ways to provide clean water, enhanced virtual reality, and a myriad of other technologies are essential to our health, happiness and safety. Training more engineers is critical to the future of our society.'

The Future of Engineering

Nanotechnology, the manipulation of materials at the molecular scale, is poised to become a critical aspect of the solutions to many of the current problems humanity faces. 'Our understanding of nanoscale phenomena is growing and nanotechnology enabled products are more and more prevalent,' says Dr Edward Davis. 'It is becoming clear that future engineers will deal with nano-enabled materials and technologies in their careers.'

However, many students just entering engineering view nanotechnology as the stuff of science fiction, and those that are interested

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in the field usually have to wait until graduate school if they wish to learn more about this promising branch of engineering. In 2014, the United States National Science Foundation identified nanotechnology as a critical area of engagement for young engineers, and started the Nanotechnology Undergraduate Education (NUE) in Engineering initiative, with the goal of funding innovative nanotechnology educational programs at the college level. The team at Auburn University secured NUE funding by proposing to develop six learning modules designed for introductory college engineering courses. A major goal of the team’s work is to bring the perception of nanotechnology from a novelty research specialty to a core component of standard engineering curricula.

In order to shape the topics of their learning modules, the team turned to the National Academy of Engineering’s list of Grand Challenges for Engineering – a collection of 14 goals for the 21st century that would dramatically improve human life, created by an international team of leading technological thinkers. The Challenges encompass broad and ambitious goals that touch many other areas of science, such as making solar energy economical, providing access to clean water, enhancing virtual reality, engineering better medicines, securing cyberspace, and improving urban infrastructure.

The Auburn team has identified ways that nanotechnology could be implemented in each of the Grand Challenges. For example, the challenge to develop carbon sequestration methods that would mitigate global climate change could be aided by nanostructures that capture carbon dioxide, while nano-engineered catalysts could help transform this carbon dioxide into useful materials. Students that participate in these modules are not only becoming literate in nanotechnology, they are also exposed to some of the key problems they will face in their careers as scientists and are encouraged to begin thinking about how they can use engineering to solve them.

Building Multifaceted Understanding

The modules are divided into three basic parts, which are designed to be adaptable to a wide range of curriculums, time constraints, and class sizes. First, students are introduced to a Grand Challenge, such as making solar energy economical. Here, they learn about the current technology used to address the Challenge – in this case traditional solar panels.

Second, students learn about potential nanotechnology solutions to the problem. For the solar energy example, this includes reduced manufacturing costs, improved light absorption, and more efficient conversion of light energy – solutions that could all be made possible through the development of advanced nanostructures. When taught at Auburn, this segment of the module often includes visits from guest speakers from industry, to help students appreciate that these concepts are being applied in the real world. This also gives them the opportunity to meet real engineers that they can relate to as people.

Third, students engage in activities that allow them to leverage their new knowledge of the Grand Challenge, while also actively learning engineering principles and skills. These include how to use common equipment, how to perform basic engineering calculations, and how to communicate their findings. In the solar energy module, students first explore the capacity and limitations of a basic store-bought solar panel, and then go on to create their own panel using nanoscale titanium dioxide and raspberry juice.

Comparing the results from these two activities gives students the opportunity to practice discussing science with their peers, thus solidifying their knowledge and understanding from the earlier lessons. To conclude the module, students work in small teams to write a comprehensive lab report that incorporates learnings from each stage of the module and develops their scientific writing skills.

The team's initial pilot projects of the modules have shown great promise in classrooms at Auburn University. When compared to students who had followed the traditional curriculum, students that had received the 'Grand Challenges' modules were significantly more knowledgeable about nanotechnology, in both objective measures and self-reported understanding. Students who had completed the modules also showed much more confidence in their ability to complete a series of nano-related tasks, than students who had taken engineering courses from the same professor, but had followed the traditional curriculum. Further, students that had engaged with 'Grand Challenges' modules showed more interest in continuing engineering classes and had more positive attitudes toward engineering careers.

Increasing Inclusion by Tapping into Values

While the Auburn team's modules are designed to increase learning and engagement for any student, they are also aimed at increasing student retention, particularly among female students and under-represented populations. Research completed by the research team indicates that female students are more likely to want to pursue altruistic careers that benefit the greater good, such as medical careers, rather than status careers that primarily benefit the individual, such as careers in finance. Traditionally, engineering has been thought of as a status career, largely due to an underappreciation for the broad reach that engineering has across science and technology.

Through grounding in the Grand Challenges, the team hopes to educate students in the altruistic roles that engineers play in society. They want to motivate female students (and altruistically-minded male students) to pursue engineering by supporting the perception that engineering is a helping profession, just as much as public health and education. 'One facet of the work focuses on understanding the motivations of students in choosing an engineering career, student perceptions and misconceptions of what engineering is and what engineers do, and how students view their future roles in society,' Dr Edward Davis notes.

As part of this aim, the team uses surveys at the beginning and end of the semester to track how students' values and perceptions of engineering and nanotechnology change through their participation in the nanotechnology Grand Challenge modules. So far, they have found that participation in the modules increases all students' perception of engineering as a potential altruistic career path, while students with instructors that did not participate in the modules showed no change in career perceptions.

The team also found that the modules that focus on human health and wellbeing, such as engineering better medicines, appeal most to female students, while modules such as personalised learning and enhanced virtual reality appealed most to under-represented minority students. They also discovered that nanotechnology itself carries a positive connotation across all student demographics, and appears to be an effective thread by which to connect modules across the varying Grand Challenges. While it is still too early to observe how participating in these modules affects the long-term retention of students from diverse groups, instructors that wish to resonate with a broad range of students can select modules that are likely to appeal to a range of demographics.

The Next Step in Engineering Education

Engineering students at Auburn University are already reaping the benefits of the nanotechnology Grand Challenges modules, and the research team plans to expand the teaching of these modules in introductory courses across the engineering college over the next year. They are developing additional modules based on Grand Challenges that students have expressed high interest in, and intend to keep refining the current modules for wider distribution outside of Auburn University, including making electronic resources widely available online.

Over the next few years, the team also hopes to extend the program to even younger students. 'Our goal over the coming years is to increase the number of schools and courses using these, and similar, modules,' says Dr Edward Davis. 'In addition, we are working to leverage our success at the college freshman level to develop programs that introduce the concepts to middle- and high-school students. The hope is that this effort will improve learning by these students and motivate them to consider engineering as a profession.'

Meet the researchers

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Dr Edward Davis earned his PhD in Chemical Engineering from the University of Akron in 1997, after completing an MSE in Chemical Engineering and BSE in Biomedical Engineering at Tulane University. He went on to spend his early career in the commercial plastics industry, holding positions at Shell Chemicals in Belgium and EVALCA in Houston, Texas. In 2007, he joined the faculty at Auburn University, where he has regularly taught courses across three different engineering departments. He currently serves as an Assistant Professor in the Department of Mechanical Engineering in the Materials Engineering Program.

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Dr Virginia Davis began her engineering education at Tulane University, where she earned both her BSE and MSE in Chemical Engineering. She spent 11 years at Shell Chemicals engaged in polymer research and development, before returning to academia to complete her PhD in Chemical and Biomolecular Engineering from Rice University in 2005. Upon graduation, she immediately joined the faculty at Auburn University, where she currently has an Alumni Professorship in the Department of Chemical Engineering. Among her many awards and recognitions are an NSF CAREER Award (2009), a Presidential Early Career Award for Scientists and Engineers (2010), and Auburn's Excellence in Faculty Outreach Award (2015).

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Dr Joni Lakin began her educational career at the Georgia Institute of Technology, completing her BS in Applied Psychology with highest honours. She continued on to the University of Iowa, where she earned her PhD in Psychological and Quantitative Foundations in 2010. She completed a postdoctoral fellowship in Measurement with the Educational Testing Service, Center for Validity Research before joining the faculty at Auburn University in 2011, where she currently serves as an Associate Professor in the Department of Educational Foundations, Leadership, and Technology. Her research focuses on educational assessment, evaluation methods, and increasing diversity in STEM fields.

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