Works in Progress: a Challenge-Inspired Undergraduate Experience

Prof. Rohit Bhargava, University of Illinois at Urbana-Champaign

Rohit Bhargava is Bliss Faculty Scholar of Engineering and Professor at the University of Illinois at Urbana-Champaign. He is a faculty member with affiliations in several departments across campus (Primary – Bioengineering: Affiliated - Electrical and Computer Engineering, Mechanical Science and Engineering, Chemical and Biomolecular Engineering and Chemistry) as well as the Beckman Institute for Advanced Science and Technology. Rohit received dual B.Tech. degrees (in Chemical Engineering and Polymer Science and Engineering) from the Indian Institute of Technology, New Delhi in 1996 and his doctoral thesis work at Case Western Reserve University (Department of Macromolecular Science and Engineering) was in the area of polymer spectroscopy. He then worked as a Research Fellow at the National Institutes of Health (2000-2005) in the area of biomedical vibrational spectroscopy. Rohit has been at Illinois since as Assistant Professor (2005-2011), Associate Professor (2011-2012) and Professor (2012-). Rohit was the first assistant professor hired into the new Bioengineering department and played a key role in the development of its curriculum and activities. He later founded and serves as the coordinator of the Cancer Community@Illinois, a group dedicated to advancing cancer-related research and scholarship on campus. Research in the Bhargava laboratories focuses on fundamental theory and simulation for vibrational spectroscopic imaging, developing new instrumentation and developing chemical imaging for molecular pathology. Using 3D printing and engineered tumor models, recent research seeks to elucidate hetero-cellular interactions in cancer progression. Rohit's work has been recognized with several research awards nationally. Among recent honors are the Meggers Award (Society for applied spectroscopy, 2014), Craver Award (Coblentz Society, 2013) and the FACSS Innovation Award (2012). Rohit has also been recognized for his dedication to teaching in the College of Engineering (Rose and Everitt awards) and he is routinely nominated to the list of teachers ranked excellent at Illinois.

Dr. Marcia Pool, University of Illinois, Urbana-Champaign

Dr. Marcia Pool is a Lecturer in bioengineering at the University of Illinois at Urbana-Champaign. In her career, Marcia has been active in improving undergraduate education through developing problem based laboratories to enhance experimental design skills, developing a preliminary design course focused on problem identification and market space (based on an industry partner's protocol), and mentoring and guiding student teams through the senior design capstone course and a translational course following senior design. To promote biomedical/bioengineering, Marcia works with Women in Engineering to offer outreach activities and is engaged at the national level as Executive Director of the biomedical engineering honor society, Alpha Eta Mu Beta.

Prof. Andrew Michael Smith, University of Illinois at Urbana-Champaign

Andrew M. Smith, Ph.D., is an Assistant Professor of Bioengineering at the University of Illinois at Urbana-Champaign (UIUC). Dr. Smith received a B.S. in Chemistry in 2002 and a Ph.D. in Bioengineering in 2008, both from the Georgia Institute of Technology. He trained with Professor Shuming Nie as a graduate student and Whitaker Foundation Fellow and continued his postdoctoral studies at Emory University as a Distinguished CCNE Fellow and NIH K99 Postdoctoral Fellow. Dr. Smith's research interests include nanomaterial engineering, single-molecule imaging, and cancer biology. He teaches undergraduate and graduate courses in Bioengineering.

P. Scott Carney, Electrical and Computer Engineering, University of Illinois

P. Scott Carney is a Professor in the Department of Electrical and Computer Engineering at the University of Illinois where he has been since 2001. His group website may be found at http://optics.beckman.illinois.edu. He teaches the ECE senior capstone course and a rotation of three advanced graduate courses in optics. He holds a PhD in Physics from the University of Rochester (1999) and was a post-doc at Washington University (1999-2001). He is a theorist with research interests in inverse problems, imaging, coherence theory and other branches of optical physics. He is coorganizer of the Saturday Engineering for Everyone

lectures, a popular lecture series for all ages at the University of Illinois. He has been named to the Incomplete List of Teachers Ranked Excellent by Their Students twelve times. He won the 2012 William Everitt Teaching Award, a prize given annually to one of roughly 400 faculty in the college of engineering, based on the nominations of his students. He was a 2009 Fulbright Scholar to the Netherlands. He is a fellow of the Optical Society of America. He has authored over 90 peer-reviewed works, a dozen issued patents and five book chapters. He is the Deputy Editor of the Journal of the Optical Society of America A and Program Chair for Frontiers in Optics, the annual meeting of the Optical Society of America. His work in medical imaging is being brought to market by Diagnostic Photonics, a company he cofounded.

Prof. Dipanjan Pan

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Introduction

Improving the undergraduate experience while increasing the number of Science, Technology, Engineering, and Mathematics (STEM) trained professionals is a recurring goal. Many students choose engineering to "change the world" and become disillusioned or lose interest[1] when faced with learning foundational concepts, which are presented without connecting the use of concepts to real-world problems. Therefore, to retain and further develop students, there is a need to connect student learning to engineering practice. We propose to create this connection by interweaving a real-world problem throughout multiple courses in the curriculum. Interweaving the problem throughout the curriculum will expose students to the same problem multiple times and require them to recall information about the problem as they investigate the problem from another perspective (engineering concept). As recall has been shown to increase long-term learning[2], we anticipate students will gain a deeper understanding of the problem while also learning how to apply multiple engineering concepts to solve a real-world problem.

To investigate this idea, we developed a challenge-inspired experience focused on a real-world problem: cancer. Traditionally, students learn engineering skills in isolated coursework without a connection to other courses or to real-world problems, facilitating loss of interest. However, we anticipate that a community of students focused on a grand challenge while progressing through the curriculum will develop interest in engineering by learning how to apply foundational principles to the problem. In the challenge-inspired model, students progress through the curriculum while also learning about the applications of concepts in courses to solving the real-world problem. By doing this, we connect students to their end goal (solving real-world problems) at the beginning of their undergraduate education and seek to increase enthusiasm by engaging students in training opportunities[3] focused around the real-world problem.

We have developed the program structure, generated details on several program experiences, identified evaluation mechanisms, and sought external funding. In fall 2014, we accepted our first cohort of students. We, herein, describe our work in developing and implementing the challenge-inspired model: the Cancer Scholars Program (CSP), http://cancer.illinois.edu/csp/.

Program Structure

The CSP is organized to engage participants from first semester on campus through graduation. Each year, a cohort of freshmen students will be selected to participate in the program; selection is based on (1) admittance to bioengineering, (2) ACT score, and (3) interest in research indicated on admission's essay. The cohort will progress through the program as shown in Figure 1. In the first semester, students will participate in the *Frontiers in Cancer Research* discovery course in which TED-style talks on cancer research are delivered, followed by facilitated discussion. Through this course, students will (1) gain an understanding of the current themes in cancer research, (2) be introduced to faculty members who mentor undergraduate researchers, and (3) develop skills in reading and discussing scientific articles. In their second semester, students will begin a research project with a faculty mentor and continue expanding on this project through their time in the program or until completion (similar to typical undergraduate research experiences; 5-10 hours/week). In summer, students will continue undergraduate research and also participate in a "research boot camp," which uses Research Experiences for Undergraduates (REU) topics as well as additional information on experimental design, statistical analysis, and written and verbal communication to further develop skills.

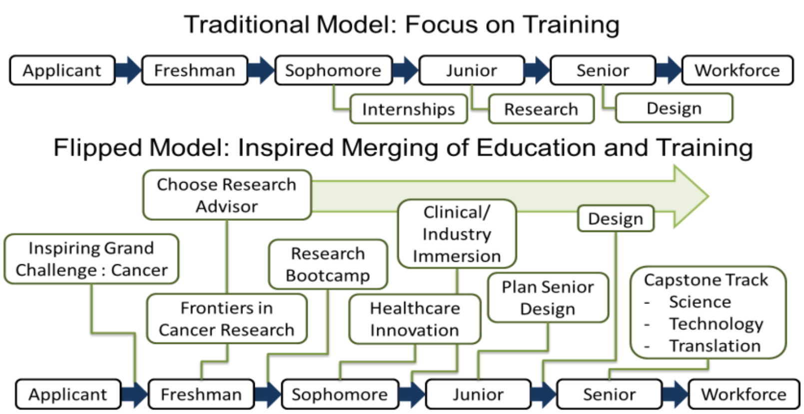

Figure 1. Traditionally, students progress through a curriculum without connecting concepts to practice. We are investigating a focused effort to connect education and training at multiple levels to a real-world problem: cancer.

As students enter their second year, the cohort will reunite in the second course of the program: *Healthcare Innovations*. In this course, contemporary issues in healthcare and mechanisms to translate research to practice will be introduced in the same format as the *Frontiers* course. Through participation in this course, students will (1) gain an understanding of factors influencing translation, (2) examine how the US healthcare policy influences research/design, and (3) discuss steps involved in translation, including clinical trials, economics, ethics, and regulatory strategies. Throughout the second year, students will continue working on their research project, with the culmination of the second year being a summer clinical or industrial immersion relevant to the project. In addition to immersion experiences, we are planning tracks: research, entrepreneurship, professional school, and industry; while these are at early stages in development, they are being developed to integrate with other campus activities.

Beginning junior year, students will continue undergraduate research while being extensively trained in engineering design, in contrast to traditional education which focuses primarily on design in the senior capstone course. The coursework for this year is not fully developed but will be based on an existing design course offered by a CSP faculty member. Training juniors in design will empower students to develop proposals for senior design projects.

In their final year in the program, students will continue work on a research project and enroll in the senior design capstone course, currently a two-semester experience. Students will also be deciding on career trajectories: graduate school, industry, entrepreneurship, or other options. We anticipate that students will identify CSP experiences (and tracks) as influences on their career trajectories.

Through the CSP, students will develop a community of support, mentoring, and intellectual pursuit. Throughout each year in the program, students will be involved in undergraduate research, interact with the CSP faculty in coursework/experiences, and participate in experiences that allow students to determine their career trajectories.

Implementation

In fall 2014, we enrolled twelve, high-achieving freshmen students (average ACT = 33.8) including: five female, four first-generation, and one underrepresented minority. All students participated in discussion in the *Frontiers in Cancer Research* course and, based on the instructor's qualitative assessment, were able to demonstrate ability to connect research topics presented over the semester. In the course, students were tasked with developing an informational video on a cancer research-related topic. The students worked in teams to (1) identify topics, (2) present the video proposal, (3) develop an outline and version of the video, and (4) develop the final version of the video. Throughout the semester, students began identifying potential research opportunities, and in spring 2015, students began working in research laboratories.

Evaluation Process

To evaluate the program, we worked with an assessment expert to identify three levels of evaluation: program design and startup, steady-state operation, and outcomes. Each level has multiple aims specified. Examples of aims and corresponding metrics of success are shown in Table 1. In addition, we plan to conduct focus groups to document student experiences and areas of improvement.

Table 1. Aims and metrics for success to evaluate the CSP

Aim	Metrics for success
Program Design and Startup	
Trainee recruitment	High-quality students applying to the program with innovative research directions
Faculty participation	Faculty co-mentors and student teams formed
Steady-State Operation	
Student progress	High retention rates; time to graduation should not be longer than for the control group
Diversity of the program	Fraction of trainees who are underrepresented, disadvantaged, or disabled
Outcomes	
Career success of students	Students: placement in research careers, including academia, industry, and government
Participant satisfaction	High satisfaction on surveys

Sustainability

To develop the program, we submitted three external grant proposals. We may consider private funding. In the first year, there were no direct faculty incentives. As the program grows, we may need to reevaluate this to gain additional faculty participation. However, the CSP provides a stipend for laboratory expenses to the group in which each CSP student works. This may be considered a small incentive to accept the student into a group.

Summary

The inaugural cohort is progressing through the CSP, and anecdotal evidence suggests that the students are engaged. Years one and two of the CSP are planned; CSP years three and four and tracks are in development. An assessment strategy has been developed, and focus groups will be used to document student experiences.

References:

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[2] J. D. Karpicke, "Retrieval-based learning: Active retrieval promotes meaningful learning," *Current Directions in Psychological Science*, vol. 21, issue 3, pp. 157–163, 2012.

[3] E. Seymour, A.-B. Hunter, S. L. Laursen, and T. DeAntoni, “Establishing the benefits of research experiences for undergraduates in the sciences: First findings from a three-year study,” *Science Education*, vol. 88, issue 4, 493–534, July 2004.

Acknowledgement: Funding in part through the University of Illinois at Urbana-Champaign’s Academy for Excellence in Engineering Education’s (AE3) Strategic Instructional Innovations Program (SIIP).