Extended Abstract - Online Community and Context Toward Scholarly and Pre-Professional Identity for Underclassmen

Kurt A. Thoroughman, Ph.D., Kathryn E. Ruzicka, Patricia L. Widder
Washington University in St. Louis, Thoroughman@wustl.edu, ruzickak@wustl.edu, pwidder9876@wustl.edu

***Abstract* - Our nation needs engineers that will drive innovation and leadership. Colleges and universities have outstanding undergraduate programs to train these rising engineers. Students receive critical elements of this training, however, only late in their undergraduate education. All engineering programs necessarily begin with foundational study, in mathematics, basic sciences, and underlying engineering principles. Explicit integration over this material, engagement with real-world products and research, and presentation of ideas usually happens only in upper-level courses. This structure of curricula is sensible given the goal of proper foundation preceding higher difficulty challenges. The big ideas and real-world challenges, however, are the elements that attract many students to engineering in the first place. Departments of engineering should meet this interest directly, as early in undergraduate education as possible. As programs meet this goal, students become engaged in larger ideas more quickly and become facile in connecting between materials, thinking broadly. With early engagement in big ideas, our students will be more adept at tackling our nation's problems and leading scientific progress in the 21st century.**

Engineering Virtual Studio (EVS) directly addresses this need by providing students with content, challenges, and community to build the full spectrum of engineering skills from the very beginning of undergraduate education.

Index Terms – Engineering education research, integrative teaching, online education, student motivation

The Biomedical Engineering (BME) Department at Washington University in St. Louis (WUSTL) features many of these pitfalls of myopia on foundation early in undergraduate training. Freshman and sophomore majors in BME at WUSTL take two full years of courses in science and engineering largely outside of BME with limited interactions with core department faculty and upper level students in the major. In the first year these courses include math, physics, chemistry, and biology; in the second year biology and math continue and is joined by computer science, electrical engineering, and chemical engineering.

FIGURE 1
ILLUSTRATION OF TWO STAGES OF UNDERGRADUATE STEM. UNDERCLASSMEN FOCUS ON INDIVIDUAL COURSES WITHOUT CONNECTING ACROSS MATERIAL. UPPERCLASSMEN SEE THESE CONNECTIONS, CAN SURVEY ACROSS THE MAJOR, ENGAGE IN INTEGRATIVE THOUGHT, AND SEE THEIR PLACE IN THE FIELD. EVS AIMS TO PROVIDE CONTEXT AND COMMUNITY FOR UNDERCLASSMEN TO SEE THIS "FOREST," NOT JUST INDIVIDUAL TREES. ORIGINAL ART BY ELLISHA MARONGELLI, 2012.

A student trains in these foundations to learn fundamental ideas around which they will build BME wherewithal in upper level classes.

This training regimen serves some students well in the eight-semester long view. Many of the benefits, however, students realize only late in their undergraduate careers. Devotion to foundations throughout the first two years generates disconnect. On one hand this foundation is critical to base upper level work; on the other hand a preponderance of the first two years is spent in serial isolation. Students easily develop disconnect from their primary motivation for the overall enterprise (Figure 1). Disconnect often segues into dispirit, which for many students leads to decreased performance or transfer to another major.

The preponderance and onerousness of underclassman foundational coursework troubles BME majors at WUSTL, but is microcosmic of student experience in STEM undergraduate study nationwide. A November 2011 article in the New York Times details the costs of this burden on students and STEM majors in the US [1]:

> But, it turns out, middle and high school students are having most of the fun, building their erector sets and dropping eggs into water to test the first law of motion. The excitement quickly fades as students brush up against the reality of what David E. Goldberg, an emeritus engineering professor [from University of Illinois at Urbana-Champaign], calls "the math-science death march." Freshmen in college wade through a blizzard of calculus, physics and chemistry in lecture halls with hundreds of other students. And then many wash out. … For educators, the big question is how to keep the momentum being built in the lower grades from dissipating once the students get to college.

EDUCATIONAL THEORETICAL BASIS FOR EVS

Pedagogical literature across academe and particular to engineering has recently recognized the advantage of introducing integration and innovation throughout a curriculum, rather than delaying bigger approaches and questions. In the National Academy of Engineering report "Educating the Engineer of 2020," a central recommendation to schools was that:

> the essence of engineering – the iterative process of designing, predicting performance, building, and testing – should be taught from the earliest stages of the curriculum, including the first year. [These experiences] connect engineering design and solutions to real-world problems so that the social relevance of engineering is apparent(.)[2]

EVS bulletins provide students with guided experience investigating a system, an open environment to consider novel solutions, and a content- and community-driven forum to evaluate and appreciate the real-world and social relevance of their coursework from day one.

An essay by Dr. Gretchen Kalonji in the same volume calls for engineering programs to "boldly reformulate engineering education [3]" to move away from "the tyranny of the assumption that 'courses' are the primary (and in many cases almost the sole) mechanisms for student intellectual development[3]." Dr. Kalonji calls for establishment of formalisms that recognize, reward, and prioritize a broader view of the big questions in engineering, societal impacts of those questions, and each student's personal investment into their role in those questions and impacts. EVS will build content, environment, and community to value exactly these goals. Students will invest in their own learning and their own identities across the curriculum, which will prime each student's passion for their interests and direct application of those interests to society.

One basis for the EVS approach lies in constructivism. According to a recent review by McDaniel and Wooldridge[4],

> Constructivist teaching methods therefore differ from traditional education in that students are expected to take responsibility for their own learning in order to actively create knowledge structures [3,5,6].

The structured elements within EVS all support this approach the examination of core concepts, integrative models, and open-ended questions with peers and a mentor; the reflection on their own skills and worldviews in the semester-ending essay; and the fostering of a community that places explicit value on the development of the person as a thinker, explorer, and inventor ready for real-world engagement, rather than solely as a student. With this "construction," students will be more flexible in applying foundations to different, new, and open questions.

ENGINEERING VIRTUAL STUDIO (EVS)

Pedagogical Engineering Virtual Studio (EVS) program aims to build support, community, and novel opportunity for our undergraduates (Figure 2). Freshman BME students register for a one-credit, pass/fail course. Students are assigned a discussion group of six peers and an upperclassman who serves as a mentor / moderator. The work required for the one credit pass is twofold: online discussion among peers, and an essay at the end of the semester reflecting on how the student is building integrative wherewithal and building his/her own focus within the major.

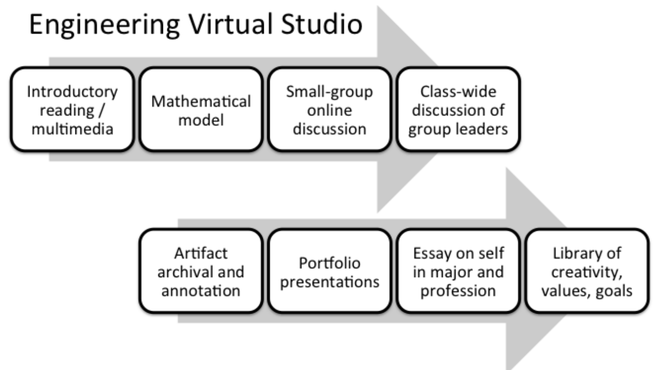

FIGURE 2
TWO STREAMS WITHIN EVS: ONE THAT INTRODUCES AND REINFORCES CONNECTION AND CONSIDERATION BETWEEN FOUNDATIONAL MATERIAL AND REAL-WORLD PRODUCTS AND RESEARCH, AND ONE THAT FOSTERS INVESTMENT INTO SCHOLARLY AND PRE-PROFESSIONAL IDENTITY.

EVS provides one "bulletin" for each course students take outside the major. Each bulletin links a core concept within that course to a real-world, current topic in BME. Each bulletin includes paragraphs introducing the connection between the core concept and real-world products and research; a review paper or multimedia that illustrates that connection; a computational model simulating that connection; and a set of questions to initiate online, integrative discussion. Each group dissects the published material, explores the computational model, and examines the discussion questions. This group work builds a local community of scholars, both pushed and supported to complement their deep foundational study with broader, more integrative consideration.

Students also build their own scholarly and pre-professional identity through EVS. During the semester students store and annotate artifacts that document their interests, talents, and aspirations. Students build portfolios of these artifacts to provide evidence of consideration of self. At each semester's end students write an essay reflecting on successes and works-in-progress toward finding their undergraduate and post-graduate goals, with identification of subsequent steps toward concretizing and substantiating those goals with evidence.

FOCUS AND FINDINGS

Our initial pilot in student self-growth, through artifact annotation, portfolio build, and reflective essay, has proven effective as a proof-of-principle that freshman can substantively integrate and grow from these investments into identity. Here we focus on the students' reflective essays. We reviewed essays after the first and second semesters (fall 2012 and spring 2013) to score three criteria:

- insight into how core curricula relates to BME
- development of a scholarly identity
- development of a pre-professional identity

We analyzed 118 essays from the first semester. Of these, 68% showed insights into connections across their curricula, 71% showed specific growth of scholarly identity, and 54% showed specific growth in professional identity. Two passages from student essays exemplified this growth:

> Classes at first appear to have no rhyme or reason, but as the semester goes on, and we learn more and more with the guest lecturers in BME 140, everything seems to fall into place. All of my classes have fed into the other, from calculus and learning about cross and dot products, to physics and stresses and strains. All which appears to be disorderly has order…
>
> This past semester has been very enlightening not just for academic reasons but it also helped me shed light on what I potentially plan to do beyond my undergraduate education. I learned that I have a passion for scientific research. From listening to professors talk about their research every class during Introduction to Biomedical Engineering to doing small projects and helping out in a lab I have found that I love research. From BME lectures I have found that cell-to-cell signaling or protein signaling systems particularly interest me. So beyond WashU I will probably go on to graduate school and pursue a PhD in either biomedical engineering or cancer biology…

Of the 96 second semester essays analyzed, 83% of the students showed at least one of the above criteria. Growth in an area was judged to be increased detail or a more mature perspective on the topic. For example, a <u>standard</u> expression of scholarly identity reads:

> The other classes that I took this semester helped with preparing me for BME classes in the future. My physics class will help with the engineering aspect of the course/future courses while the chemistry and biology will help with the biology aspect of the course future courses. I can't wait to take my next BME class and see how I can apply the concepts I've been using in these other classes…

While a <u>growth</u> expression of scholarly identity reads:

> Although initially I thought that biology was too difficult and possibly some of the concepts were unnecessary, over time I began to see how the things we learned fit together and how they fit with the things I learned in my previous semester. For example the lectures over cell systems, signal transduction, and repression helped me understand how the drugs would interact in the body and the lectures on sequencing, transcription, and translation helped me understand how the next generation sequencing we learned about in BME 140 truly work...

The standard expressions still dominated the results – 45% curricula insights; 30% scholarly identity; 38% pre-professional identity – but there is growth in all criterion areas: 23% of students expressed growth in developing scholarly identity, 11% of students grew connections between core life sciences courses and BME, and 8% better nurtured their pre-professional identity.

Through the examination of the essays, we noticed that many student essays did not address all three areas, and there was an overall *decline* in the percentage of students who reflected the desired criteria in their writing. This could be because the prompt for the spring essay was essentially the same as for the fall essay; this could have stymied students' meaningful reflection. Many students simply wrote about feeling overwhelmed and stressed, and were unable to muster much enthusiasm for the assignment or BME in general. Many of the spring reflective essays were quite short, perhaps an indication that the students were unable to devote much energy to the process of reflection.

LESSONS LEARNED

The vignettes presented here reveal qualitatively that students engage in both threads, connecting foundational ideas to real-world engineering and building their own identities. Our analysis of the semester-ending essays provides a baseline of evidence for student summative consideration across the semester, but room for improvement, especially upon repeated assessment in later semesters. We have, however, shown a proof of concept, that a lightweight, online intervention can provide context and community for engineering underclassmen who otherwise would be predominantly or wholly disconnected from the major during foundational coursework.

REFERENCES

[1] Drew C. (2011) "Why Science Majors Change Their Minds (It's Just So Darn Hard)." New York Times, November 4th.

[2] National Academy of Engineering. (2005) Educating the Engineer of 2020. Washington,DC: National Academies Press.

[3] Kuhn D. (2007). Is direct instruction an answer to the right question? Educational Psychologist, 42(2), 109-113.

[4] McDaniel MA and Wooldridge C. (2012) "The Science of Learning and its Applications." In Effective College and University Teaching (Buskist W and Benassi VA, eds). Thousand Oaks, CA: SAGE Publications.

[5] Von Glasersfeld E. (2005). Introduction: Aspects of constructivism. In C. T. Fosnot (Ed.). Constructivism: Theory, perspectives, and practice. New York, NY: Teachers College.

[6] Tobias S. and Duffy T.M. (Eds.). (2009). Constructivist instruction: Success or failure? New York, NY: Routledge.

AUTHOR INFORMATION

Kurt A. Thoroughman, Ph.D. Associate Professor of Biomedical Engineering; Director of Undergraduate Studies, School of Engineering and Applied Science, Washington University in St. Louis, thoroughman@wustl.edu

Kathryn R. Ruzicka Administrative Assistant of Undergraduate Studies, Department of Biomedical Engineering, Washington University in St. Louis, ruzickak@wustl.edu

Patricia L. Widder Lecturer and Teaching Lab Coordinator, Department of Biomedical Engineering, Washington University in St. Louis, pwidder9876@wustl.edu