High Impact Practices toward Personal and Professional Identity in Introductory and Advanced Engineering Seminar Courses

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***Abstract*— Engineering educators have struggled with engaging students throughout their studies. Traditional coursework provides little opportunity for holistic integration, personal connection, and professional relevance. We have integrated high-impact practices within our required curriculum. One element is a new, required, one-credit seminar for students beginning their engineering coursework. The seminar is very student-centered, dominated by discussions connecting technical concepts with real-world context. The lecturer is a professional engineer; he hosts visiting engineers to discussions. The course modules foster understanding in ethics, professionalism, community needs, and connection to industry and government. In a second element, we have also integrated new integrative modules into existing capstone seminars within each major. This novel pairing provides students opportunities for reflection and integration within required coursework. Our overall goal is to cultivate a learning community of the whole, within which students experience their coursework in constant contact with the broader world and with persistent progress toward their own holistic education.**

Keywords—holistic education; pre-professionalism; first-year education; senior seminars

I. The Challenge: Holistic Engineering Education

This work addresses a critical problem in STEM undergraduate education and in engineering education in particular. The heavy preponderance of evidence shows that the American workforce lacks the combinations of skills to face and overcome the technical challenges of today and tomorrow [1]. A particular framing of the issue arises from IBM and Michigan State in their recent efforts toward prioritizing "T-shaped" graduates [2]. Deep technical expertise for these students is matched with broad understanding of other disciplines and worldly knowledge. Such preparation promotes meaningful collaboration across experts to generate transdisciplinary teams and solutions to difficult challenges of local and global importance. What was once decried as "soft skills" is now viewed as critical for productivity: as individuals, in companies, and across the nation [3].

Broader connection to identity, real-world, and pre-professionalism is particularly vital to engineering. For over a century, educators of engineering have struggled with interleaving breadth with depth [4]. Human-scale connections to real-world problems, however, define the societial value of engineering, and frame modern perspectives for engineers of the 21st century [5]. While the aspiration is clear, many students instead experience strong disconnect between their curriculum and relevance to their personal inspiration or to real-world aspiration [6].

A potential solution to this gap arises from extracurricular, real-world opportunity. Both at Washington University and nationwide, students have unprecedented access to authentic experience with real-world problems, through student groups and with direct employment with practicing engineers [7].

A very vexing problem, however, is how to provide students worldview that integrates across curricular and extracurricular training. A preponderance of coursework is "foundational," covering topics that truly undergird a discipline, but with little or vague connection to current real-world problems [4]. Although the extracurricular experience broadens vantage points and knowledge of students, a duality develops: disconnection from the curriculum as staid and irrelevant, and connection to external opportunities as vibrant, current, and meaningful [8].

II. Our Approach: High-Impact Practices within a Unique Undergraduate Engineering Program

A. Our Regional Engineering Education Collaboration

Our work here aims to improve student performance and pre-professional preparation in The University of Missouri-St. Louis/Washington University Joint Undergraduate Engineering Program, a unique partnership between a public university and a private university to provide accredited engineering degrees to nontraditional students in the St. Louis region [9]. Degrees are offered in civil, electrical, and mechanical engineering, with all of the engineering classes offered on the Washington University campus in the evenings.

Most students enter the joint engineering program after foundational coursework, taken either at UMSL or a local community college. Our joint engineering program is the

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primary option for an engineering degree for students who are constrained to live in St. Louis and come through the community college or are returning to school after starting another career.

As a result, the joint engineering program plays a unique and important role in preparing a diverse engineering workforce for the region. Faculty at both institutions have provided introductory material and scientific foundation (UMSL) and upper-level, traditional engineering curriculum (WUSTL). A majority of the faculty in the engineering courses are adjunct. These dedicated professionals from local industry have, throughout the program's 23-year history and through today, formed the bedrock of practical scholarship from which students learn engineering theory and skills. These three influences have helped mold effective engineers and local leaders in our technological community.

In this work-in-progress we describe commitment and cultural change to build professional engineers across all elements of training; to integrate our cultures and our communication with students; and to foster a truly student-centric community within which all program elements clearly dovetail, through each student's education, into training toward engineering professionalism. Our novel structure – students from our region, very often working part-time; many lecturers in our program part-time, while serving as professional engineers in the same region – makes our program very unique, and a model system for integrating holistic leaching and learning into the main fabric of our majors.

B. Our Connection to a National Consortium across Academe and Industry

We have built this work-in-progress in connection with a new consortium arising from the Business - Higher Education Forum (BHEF). Five regional sites worked with BHEF to develop a proposal, toward improving undergraduate STEM education through innovative collaboration [10]. The theories of change and plans of action arose from scholarship within the American Association of Colleges and Universities (AAC&U) and its partners. Over many years AAC&U have refined High-Impact Practices, educational elements that provide students community, connection, content, and context to invest holistically, to build their own depth and breadth of understanding [11]. Many studies have shown that adopting several of these Practices promote achievement of Essential Learning Outcomes. These Outcomes encompass breadth and depth; connection to personal and worldly concerns; awareness and appreciation of societies, professions, and citizenship [12]. Although AAC&U generated these guidelines to apply across all two- and four-year programs, these Practices and Outcomes parallel very closely the aspirations of the STEM and engineering education communities toward holistic, connected, personalized, and worldly graduates.

The BHEF initiative, and the participation of our program therein, aims to improve success of students originating in community colleges. Our perspective mirrors that of AAC&U: to insure full accessibility to best practices, we need to make those practices part of the required curriculum, rather than elective or accessible only through extracurricular or cooperative activity. Foundational literature discovered that High-Impact Practices often did not reach those in most need, as limited time and money kept at-risk students from engaging in ancillary activities [13]. An additional primary goal is to treasure the diversification of our educational system by embracing the centrism of each student, including their identities, cultures, and worldviews. Engineering education, in particular, is greatly strengthened by incorporating this diversity in our selection of, and approaches to solve, real-world problems [14]. This variety can and should broaden and deepen the vitality of our own courses, and our diverse, often part-time student population can contribute this diversity and be recognized as important peer educators within main elements of our curriculum.

C. Our Implementation of High-Impact Practices across an Undergraduate Engineering Program

To date, we have focused on High-Impact Practices that, in the AAC&U vernacular, are First-Year Seminars and Senior Capstones. We need to modify this context, as in our multi-stage program, many students complete curricular elements at different rates. We therefore parallel the "First-Year" experience by providing a new one-credit seminar, required of students as they begin their engineering coursework on the Washington University campus.

This one-credit hour seminar introduces a holistic, professional formation approach to engineering education. This seminar helps students build real-world understanding of business, ethics, and society; integrate real-world perspective with traditional coursework; and build their own professional identity. Students will learn from local leaders in industry and work in teams to explore modern problems and solutions.

Our three majors (Civil, Electrical, and Mechanical) have extant capstone design courses. As with most senior design, these projects are stand-alone and do not contribute to building holistic, connected, "T-shaped" engineers. We therefore have applied the mindset of the "first-year seminar" to modules in upper-level coursework. Two of the three majors have established seminars, taken late in the major. We have added modules to revisit, explicitly, elements of holistic and real-world connections. In particular, the isolated nature of engineering courses, culminating with capstone design, can leave students with the false impression that the design course most parallels professional engineering work. Instead, the literature on engineering education in the 21st century, STEM-wide investment in T-shape, and reports from industries agree that the whole of the major is critical. Different elements of each job, and sometimes entire careers within engineering, can rely on analysis, test, writing, communicating, teamwork, and real-world connection just as much as traditional design [15].

Our work-to-date, therefore, is to foster holistic learning, through a new lower-level seminar and through new modules in existing upper-level seminars. The overarching goal is to foster broader, deeper, more personal, more worldly mindset, within required major courses.

III. Work-In-Progress Results

A. Organizational Change

To make room for the new seminar, we consulted with our program Continuing Improvement Committee. We simplified the requirements for each major. We then proposed and passed, through this committee and the full faculty, the seminar as a required course in all three majors.

We recruited a local civil engineer to implement and teach the course. He owns a firm of engineering contractors and has extensive local civil engineering experience.

B. One-credit, lower-level seminar

This seminar provides students with modules to discuss, reflect, and integrate over elements of professional engineering. Each module features a reading introducing a topic, such as leadership, ethics, or diversity. The students then discuss the topic with an engineer, either the course lecturer or a visiting expert. As the lecturer described,

My strategy had been to introduce the students to the subject matter prior to a speaker or workshop. When we have a speaker involved we have a very open discussion filled with challenging and thought provoking questions.

Prior to our next class, following our breakout session, the students are asked to write a reflection not to exceed a page where they are to share an experience that is relative to the subject matter and offer their perspective.

We then break into small groups of 4 to 5 where they share with each other their different perspectives for no longer than 25-30 minutes. The students elect a speaker and they present the notes from the group break out. During this time, I challenge the students to explore that think about the results of their break out analysis.

This formalism requires each student to engage: with the material, with each other and practicing engineers, and with developing their own deep and broad understanding of engineering professionalism.

C. Student-centric elements in upper-level seminars

The upper-level seminars are specific to each major, enabling a deeper connection between each student's established study within the field and emergent professional mindset and opportunity. We recruited the director of our Engineering Communications Center to teach the mechanical engineering seminar. The seminar focused on case studies, successful and not, arising from real-world examples. These formed the bases for modular discussion and integrative discussion spanning this seminar and the rest of the courses in the major. The semester ended with a series of debates. The lecturer shared,

I really enjoyed teaching the seminar last fall. I had a class that was poised to discuss and debate with enthusiasm. Though it was an hour class, it lasted longer and the students didn't seem in a hurry to leave when the discussion or debates ignited some conversation.

In a different seminar, for upper-level civil engineering majors, the lecturer (and director of that major) had already incorporated several elements oriented to discussion and student-centrism. In broader discussion of our program-wide intervention, we discussed the texts from the National Academy of Engineering and the analogues from civil engineering. Throughout, these texts emphasize broader skills and deeper connection between many curricular elements and real-world issues. In this first year of work-in-progress, the lecturer explicitly incorporated these texts into the seminar. As the lecturer shared,

The assignment … got the vast majority of students to admit they had not looked at Civil Engineering beyond 'being a designer'. The general assumption was that the CE of the future would likely become a 'technician' or 'number cruncher' as software developed. Many expressed had that they hadn't considered how the role of a Civil Engineer could change within their professional lifetime. Throughout the semester we took a detailed look into the 'Vision' documents [16, 17] which proved 'enlightening' for many.

Most students appreciated the introduction to the Professional Development (PD) skillsets. Several commented that they assumed CE's were 'behind the scenes' within the Built Environment, and consequently would not need (or have much use for those skills) in their professional role. Almost all included further development of their PD skillsets in their Lifelong Learning plan.

IV. Conclusions and Next Steps

In summary, with interventions that are lightweight in scope, we have initial evidence of progress. We have demonstrated deeper connection and broader consideration across majors and across stages of development in our program. Part of our success has been overcoming barriers to organizational change to implement these interventions [18].

We have identified four key steps that have enabled our success to date:

- An education researcher and administrator and the dean of the program (the authors of this work) collaboratively built the long term goals and strategies.
- We presented those goals and strategies, with initial implementation plans, with our curriculum committee and the full faculty, for feedback and approval.
- We designed holistic goals of curricular modules. We then coordinated with lecturers, who dovetailed these goals into their own material.
- We have constantly communicated with these lecturers to provide a positive feedback loop, supporting development in individual courses and across the program.

In all these steps we explicitly connected to the broad identities of our students and faculty, many who have lives that span academics and industry.

An immediate next stage is to establish a senior seminar in electrical engineering, to parallel the ones in the other two

majors. Each student will then have a complete implementation of integration, from formative establishment through summative reflection of the curriculum, all toward stronger ties inward to identity and outward to professionalism and citizenship.

With repeated offerings, we will develop and implement more rigorous qualitative assessment of individual student growth. We also aim, at full scale, to gather select discussion sessions across lower and upper levels, fostering near-peer teaching and learning. A final element, under development, will be establishment of a hands-on facility, including maker space and testing equipment. Although this space will support entrepreneurial and independent student activities, it will also enrich projects in required courses, enabling students to extend beyond theoretical consideration and build viable physical solutions within their coursework. Our lecturers visiting from industry can advise these projects, thusly deepen the meaningful connections between the classroom, the engineering profession, and the challenges and opportunities of our community.

The whole of the intervention – formative contextual discussion, frequent group work in the engineering labs, and summative reflective discussion – aims to generate a through line across our program. On one hand these changes are lightweight; much of our majors will remain the same. The through line, however, will provide a backbone or a scaffold, onto which faculty and students will grow their own culture of integration and connection. We aspire for this culture to bring out the amazing strengths in our program, elements that are community members share but also opportunity through nurturing and integrating individual and group diversities [19].

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