Vision for State-of-the-Art Mechanical Engineering Education at UW Seattle and Tacoma

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The University of Washington at Tacoma is uniquely positioned in proximity to a diverse student pool with identified interests in Mechanical and Civil Engineering; furthermore, there is ample physical space for growth at UW Tacoma, with significant unmet demand among regional industries to hire Civil and Mechanical Engineers. UW Tacoma has ABET accredited undergraduate degree programs in Electrical and Computer Engineering, as well as graduate degree programs in these disciplines, so that the development of BSME and BSCE programs will leverage existing strengths, promoting collaborative multi-disciplinary capstone design as an integral component of its engineering curriculum.

This document highlights the efforts, during autumn quarter 2019, of a small team of doctoral candidates[1, 2] at the University of Washington Seattle, who are keenly interested in exploring their potential for academic career pathways. Along with a course coordinator[3], these graduate students have reflected upon their own experiences as undergraduate students, and they have reviewed a recent (March 2018) report on "The Global State of the Art in Engineering Education" by Dr. Ruth Graham, which identifies key attributes, in common, of excellent engineering education among 'current and emerging leaders' worldwide.

Herewith are described the results of our discussions over the past quarter (autumn 2019), prioritizing what we believe to be the ten most important attributes of leading engineering education programs. Thematically, these ten attributes address the potential for ***what*** would be the ***content*** of UW Tacoma's Mechanical Engineering curriculum (core and ancillary), ***how*** the new BSME program would engage engineering students, and ***who*** would participate in state-of-the-art educational experiences that grant UW Tacoma graduates a diverse range of leadership opportunities as they launch their own careers.

We additionally provide, in Appendix A, a list of freshman and sophomore-level prerequisite courses offered at nearby community colleges. In Appendix B is a proposed four-year BSME course sequence for UW Tacoma. We further provide in Appendix C a complete listing of all proposed BSME courses in chronological order; each course is listed along with the year and quarter the prerequisites would be taken, to show that the courses are ordered appropriately. Appendix C guideline ensures that in the process of completing the recommended course sequence, students would not be enrolled in classes for which they are not prepared. ABET syllabi from UW Seattle's Mechanical Engineering Department[4] (recent 2019 ABET accreditation cycle) are provided in Appendix D.

[1] UW Seattle Mechanical Engineering doctoral candidates: Anthony Anderson, Molly Carton, Michael Rosenberg, Malia Steward, Melicent Stossel and Tyler Williams

[2] UW Seattle Civil and Environmental Engineering doctoral candidates: Andrew Makdisi and Sarah Wichman

[3] UW Seattle Mechanical Engineering Associate Professor Ann Mescher

[4] UW Seattle Mechanical Engineering Professor and Associate Chair John Kramlich

What is the proposed *content* of UW Tacoma Mech. Engineering curriculum?

Attribute 1: Rigor in Mechanical Engineering Fundamentals

Mechanical engineering fundamentals are the foundational principles for solving engineering problems that involve solid mechanics, statics and dynamics, vibrations, controls, system analysis, materials, thermodynamics, fluid dynamics, and heat transfer. Rigor in engineering fundamentals improves concept mastery for students, deepens their appreciation of fundamental principles, and builds their confidence, founding and ultimately strengthening individual and team capacities to solve real-world problems.

Attribute 2: Attention to State-of-the-Art in Engineering Research

Attention to state-of-the-art in engineering research exposes students to present-day research advancing the state of engineering knowledge. Student's exposure to current research can become part of the overall fabric of the undergraduate learning experience, fostering the mission of life-long learning. Faculty and graduate students alike report that were it not for their exposure to research opportunities as undergraduate students, they might never have considered research-focused careers. The opportunity for undergraduate students to participate in research is absolutely essential for any leading program in engineering education.

Attribute 3: Attention to State-of-the-Art in Engineering Practice

Competitive businesses, military defense, public works and non-profit organizations (NGOs) all attend continuously to the state-of-their-art in practice; simultaneously, a student's exposure to state-of-the-art in engineering practice reinforces and motivates her deepening understanding of mechanical engineering fundamentals as they are applied to immediate and near-term problems. In analogy with Attribute 2, exposure to competitive engineering practices can become part of the overall fabric of the undergraduate learning experience, fostering the mission of life-long professional development and learning. Healthy attention in the curriculum to current engineering practice promotes excitement and anticipation as graduates identify career pathways within public works, NGOs, and competitive marketplaces, including graduates who will ultimately start their own businesses, solving near-term, real-world problems.

Attribute 4: Curriculum Balance between Individual Proficiency and Teamwork

Multi-disciplinary teams are powerful in their capacity to solve problems across two or more engineering disciplines; however, any multi-disciplinary team will find itself unable to function at peak efficiency without strong individual proficiencies in each of their respective specializations for the problem at hand. Leading engineering programs provide ample opportunities for students to develop individual proficiency throughout the curriculum, and at the appropriate time(s) in the degree program, opportunities are offered to encourage students to demonstrate both their individual proficiencies as well as near-optimized performance of an intra-disciplinary / multi-disciplinary team.

How will the new BSME program engage engineering students?

Attribute 5: Overall Culture of Hands-on Learning

With ever-increasing virtual distractions in this digital-age, an *overall culture* of productive, hands-on learning in mechanical engineering is as essential as ever for any state-of-the-art engineering program. Analogous to the old adage, "a picture is worth a thousand words," carefully designed classroom demonstrations or more involved laboratory experiments that small teams of engineering students carry out are *far more effective for student learning* than a thousand written words. This is not to say that words in textbooks should be removed, nor that *all* of engineering learning should be *solely* experiential, but rather that *while* students explore and study fundamental concepts, those key principles can be illustrated and further absorbed in straightforward hands-on learning experiences. In all leading engineering programs, the reinforcement and founding of well-established engineering principles for students occurs via hands-on learning experiences distributed throughout the curriculum.

Attribute 6: Project-based Learning with Real-World Context / Intrinsic Motivation

Within a year of entering leading programs, first-year engineering students are introduced to real-world service projects that motivate individuals and teams to *actively practice* the steps of design *processes*. In some emerging programs, student teams have the opportunity to self-select projects that excite their interests and also meet specified criteria for project-based learning. Emphasis in the first half of the curriculum is placed on *learning process steps* rather than mechanical engineering analyses. Early introduction to design / solution *process steps* provides students with the framework(s) needed to approach and solve any general problem, inclusive of engineering coursework and preliminary open-ended design problems, ultimately leading to capstone design. Minimally, the capstone design experience exercises a range of mechanical engineering analysis skills within the design *process / solution steps* that were first introduced in the entry year of the program.

Attribute 7: Collaborative Multi-disciplinary Capstone Design

As a culminating experience of the undergraduate degree program, capstone design potentially transforms mechanical engineering *students* into *functioning* engineers. In the majority of leading programs, capstone design is carried out over two semesters (or three quarters) of the final year, extending beyond problem definition / scope and design-on-paper into prototyping and testing phases. With large cohorts, intra-disciplinary capstone design is most typical and is highly effective with small mechanical engineering teams of three to four students. In emerging (smaller) programs, multi-disciplinary collaborations provide additional opportunities for engineering students to further stretch their communication and problem solving skills beyond mechanical engineering, enabling potential solutions for more complex real-world problems.

Who will participate in UW Tacoma BSME educational experiences?

Attribute 8: Diversity in the Student Body, Faculty and Staff

Diversity in the student body, departmental faculty and staff optimally provides an inclusive and engaging learning environment for a diverse set of perspectives and talents to address engineering and other multi-disciplinary, real-world problems. As real-world problems frequently do extend well beyond engineering disciplines, a rich diversity in backgrounds and perspectives of participants is critical for near-optimal educational experiences.

Attribute 9: Flexible / Blended State-of-the-Art On-Line Learning

Flexible and blended on-line learning allows students to carefully study and review challenging concepts and fundamental principles that should be mastered for full engineering proficiency. As an example, experienced Fluid Mechanics instructors are able to develop without the aid of notes the Navier-Stokes equations, beginning with the equivalence of applied forces, $\Sigma \mathbf{F}$, to the product of mass and its resulting acceleration, $\Sigma \mathbf{F} = m\,\mathbf{a}$. For mechanical engineering students, the resulting Navier-Stokes equations are overwhelmingly complex; most students correctly perceive these equations to be nearly impossible to solve mathematically, but indeed, there are simple cases for which the equations are solvable. With well-prepared in-class lectures, supplemented by on-line resources for review both prior and subsequent to in-person meetings between students and instructor, these most challenging principles can be learned quite well in an undergraduate degree program. While on-line learning is an extremely valuable tool as a supplement for student's careful review, it is important to note that *there are no **leading or emerging** engineering programs that offer on-line learning exclusively*.

Attribute 10: Options for Diverse Career Pathways / True Leadership Development

Leading and emerging programs in engineering education offer a breadth of opportunities for students to develop true and lasting leadership skills, uniquely suited to individuals. As mentioned in *Attribute 2*, we view opportunities for undergraduate research (e.g. NSF REU) as essential in any leading engineering program. Analogously, students who have excelled in undergraduate engineering coursework could be offered an opportunity to "intern" with an experienced instructor as an undergraduate grader or a laboratory teaching-assistant. Summer internships should include not only traditional company-sponsored internships, but might as well extend to service-based internships with NGOs or other non-profit organizations. Individuals interested in patent law could work as summer interns in an appropriately recognized local law office, and students with political interests could intern as legislative aides in Olympia while they are engaged in the BSME curriculum. Increasing the disciplinary breadth of student internship opportunities serves to optimize the educational experience for all, and it tremendously enhances the capability of graduates to choose life-long careers in which they will be most passionate and effective.