WASHINGTON UNIVERSITY MCKELVEY SCHOOL OF ENGINEERING

STRATEGIC PLAN TO ACHIEVE LEADERSHIP THROUGH EXCELLENCE

EDUCATION

Enhancing Undergraduate Curricula

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Executive Summary

The School of Engineering & Applied Science has an opportunity to take the lead in undergraduate education among its peer institutions. Input from students, faculty, and alumni has led to three areas of focus.

- **First-year Engineering Experience.** The needs and expectations of today's upcoming undergraduate engineering students are evolving. Revising our first-year engineering structure to speak to the unique needs of incoming engineering students will help us continue to attract and retain the highest-quality undergraduate applicants.

  Our current first-year courses should be better coordinated across departments. The first semester should provide a meaningful orientation and exploration of various engineering disciplines and begin developing crosscutting engineering skills such as computing and computer-aided design. Discipline-specific courses in the second semester should further introduce key concepts and reinforce the crosscutting skills.

- **SEAS Incentives for Teaching.** Evidence-based best practices in engineering education demonstrate improved student outcomes, and national rankings of universities are reflecting the expectation that these methods will be practiced.[1] Creating an incentive structure that rewards best teaching practices among all faculty members will demonstrate our commitment to the highest-quality undergraduate education and set us apart from our peer institutions.

  While some instructors have embraced evidence-based best teaching practices, most of our courses adhere to the classical lecture format. A Director for Education Innovation should be hired to spearhead and oversee the reforms. Resources should be committed to hire personnel with engineering backgrounds (e.g., science teaching and learning fellows) who would first be trained in best teaching practices and would then closely work with instructors to implement changes.

- **Renewed Focus on Outcomes.** A renewed curricular focus on the ways in which our teaching of engineering fundamentals leads to marketable outcomes desired by our students' future employers (industry, government, graduate school, medical school) will increase the attractiveness of our graduates and improve placement in the next step of their choice. The curriculum for each degree program should be critically evaluated with emphasis on content and skills relevant to contemporary practice. Problem- and project-based learning should be distributed vertically across the curriculum to engage students at all levels in designing, coding, making and measuring.

[1] 2016 WSJ-Times Higher Education Rankings allot 20% of the scoring to Engagement: Student engagement 7%; Student recommendation 6%; Student interaction 4%; Subject breadth 3%. Test scores and selectivity 0%.

First-Year Engineering Experience

Many high-achieving candidates for top engineering programs are attracted to programs that offer major choices with a high degree of first-year flexibility and versatility. They are also eager to learn the skills and engage in practical applications of their new chosen field. Many may not have a well-formed understanding of what their field involves, and a high percentage of our Engineering students change majors during their undergraduate career.

A careful restructuring of our first-year Engineering experience can:

- Introduce core engineering skills common to all disciplines
- Provide meaningful hands-on applications of each engineering major
- Involve collaborative experiences to build teamwork and communication skills
- Remove barriers to early changes in engineering majors
- Give students what they need to make better-informed decisions about their major and career goals

One solution is to provide a mechanism for Engineering students to explore more than one engineering major in their first year, though they would still declare a major. For example, the introductory semester for BME, EECE, ESE, and MEMS could be organized into two or three discipline-specific modules, similar to the approach taken at Vanderbilt University. (The CSE department is structured differently, and CSE students have different needs from those of the other engineering majors; thus a different approach would be needed for them.)

Students would choose the two or three disciplinary modules based on their interests. The modules would be treated as separate one-credit classes organized and operated by the major departments. Content of the modules would be coordinated among the departments to ensure that a core set of skills is taught in each, such as CAD, MATLAB, Engineering Design, and Technical Communications. In addition to these project-based core skills, class time would be devoted to lectures informing students of current research, real-world applications, and the various career paths followed by graduates in the major, including lesser-known paths such as government, law, and business. Presentations could be made by research faculty, industry representatives, and local entrepreneurs. This introductory set of courses would be required for all non-CSE engineering students.

The project-based core skills common to all engineering majors listed above could be introduced at the first-year level regardless of their high school course preparation. Introducing basic skills in the introductory class would provide interesting hands-on applications, lay the foundations for more advanced work in upper-level classes, provide collaborative experiences, and help students decide not only if their chosen major is a good fit for them, but also whether their career interests lie in research, industry, or entrepreneurial paths.

Success in this strategic initiative involves not only attracting but retaining the highest-quality engineering undergraduates, as their first-year experience is critical to their success in their major.

SEAS Structural Financial and Career Incentives for All Teaching Faculty

We have the opportunity to take the lead among research institutions in teaching our undergraduates. It is well demonstrated that quality contact with faculty improves student outcomes and enhances their overall experience. Students who say that their professors are engaged with teaching and provide a well-run course not only learn the material more effectively, but also are more confident about their knowledge base, which can translate to a better transition to their chosen next step. These students are also likely to respond positively to national rankings surveys and become supporting alumni.

We are fortunate at WashU to have many highly-engaged faculty who care deeply about the teaching aspect of their career and a school strongly committed to growing and nurturing a Teaching Core. It is difficult, however, for many faculty to devote the necessary bandwidth to learn about and incorporate evidence-based active learning practices into their courses. We therefore have an opportunity to set ourselves apart from our peer institutions by creating an environment where students have not only access to top researchers, but also the highest quality of undergraduate education available. By providing *training, resources, evaluation, and incentives,* we can achieve a quantum change in our undergraduate teaching.

Training

Just as research techniques have evolved over time, the best teaching methods have evolved over the past few decades. A large body of educational research has demonstrated improved educational outcomes when interactive teaching methods are thoughtfully applied to STEM education. It is a fair assumption that nearly all teaching faculty wish to be effective teachers; better educational outcomes make a more positive experience for students and teachers alike. Training in best practices and consultation with engineers who are teaching experts can help faculty to make incremental changes to or complete overhauls of existing courses to improve their teaching effectiveness.

When implementing training, considerable attention should be given to providing robust, required teaching training to new faculty. As new faculty set up their first courses in SEAS, they should receive training in contemporary teaching methods and also become acquainted with the tools and resources available to them. Incorporating effective teaching methods from the beginning would have a significant long-term impact on our overall teaching quality.

In addition, we should provide clear expectations and effective training to teaching assistants. Due to their large enrollment and number of courses offered, our CSE department in particular uses a significant number of TAs. By providing training and incentives for excellence in teaching assistantships, we can better support our teaching faculty and improve student outcomes.

Resources

If our faculty members are to achieve the goal to improve undergraduate education, we must provide them with the resources to do so. This may include additional technology, skilled teaching assistants, or a semester without teaching to focus on improvements. One mechanism that should be considered is to bring in teaching-focused engineers to work directly with departmental faculty. These would be engineers with additional training in teaching innovations who could expedite the process by working directly with faculty to find methods that work for both the instructor's teaching style and the course material.

Evaluation

Recognizing good teaching requires methods of evaluation that correlate positively with desired student educational outcomes. Common methods to evaluate teaching, such as student course evaluations, do a poor job in this regard — in fact, correlation between student evaluations and measures of learning is low to negligible.[2] In addition, any method of evaluation must be fair, must hold over the broad range of sizes and subjects of courses offered, and must be independent of the many variables outside the instructor's control.[3]

The Teaching Practices Inventory[4] is an example of a method to evaluate STEM disciplines that is independent of both student evaluations and factors such as course size and difficulty of material. By measuring and tabulating best practices in seven categories, it corresponds well to the metrics of evaluation of research. Similar to research proxy metrics, the Teaching Practices Inventory is meaningful due to the strong correlation between STEM teaching best practices and desired student educational outcomes.[5] (It should be noted, however, that the Teaching Practices Inventory does not apply well to lab-only or entirely project-based courses.)

Institution Level Incentives

Research institutions have a well-established system of incentives for faculty career progression based almost entirely on measures of research production and prominence. Though nearly all faculty are expected to teach, the research-based incentive system means that faculty who take time and energy away from research to devote to teaching are effectively penalized. It is not surprising that teaching is often given the minimum amount of attention; though nearly all faculty want to teach well, one cannot blame tenure-track research faculty for devoting their energies to those things which lead directly to their career success.

Wieman et al.[6] demonstrated that "the institutional incentive system is the dominant barrier to adoption of both better teaching methods and collective departmental practices that would make education more effective for the students and teaching more efficient for the faculty." Though interactive teaching methods, such as active learning and introducing technology into the classroom, are shown to improve student engagement and resulting outcomes, without institutional incentives to implement them, progress can be expected to be spotty at best. Our Teaching Core, however, can be expected to be early adopters because it is responsive to their mission to be continually working on implementing educational innovations.

This incentive system, then, is where SEAS can differentiate itself. Though many institutions encourage better teaching and make training available, few, if any, research universities incorporate an objective teaching evaluation into their financial and career incentive systems. This incentive system may take a number of forms, but it must be real, positive, and persuasive.

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[2] Clayson, D. (2009) Student evaluations of teaching: Are they related to what students learn? J. Marketing Education, 31(1), 16-29.

[3] Pascarella, E., & Terenzini, P. (2005). How college affects students: A third decade of research. San Francisco, CA: Jossey Bass.

[4] Wieman, C. & Gilbert, S.L. (2014) The teaching practices inventory: A new tool for characterizing college and university teaching in mathematics and science. CBE-Life Sciences Education, 13, 552-569.

[5] Wieman, C. (2015) A better way to evaluate undergraduate teaching. Change:The Magazine of Higher Learning, 47:1, 6-15.

[6] Wieman, C. (2016) Improving Undergraduate STEM Education at Research Universities: Case Study 1, the Science Education Initiative.

Outcome-Focused Curriculum

Many suggestions from students and alumni detailed ideas to improve job opportunities for our graduates, whether it be graduate school or industry. Common themes included:

- Integrating interpersonal skills such as networking, leadership, collaboration, and communication throughout the curriculum
- Offering a common engineering computing course for non-CSE majors
- Incorporating a project into every course, unless a compelling case can be made not to
- Instilling a spirit of design thinking, problem solving, and practical application wherever possible in the undergraduate curriculum
- Engaging industry representatives across a broad range to incorporate real-world applications of engineering skills
- Creating opportunities for cross-disciplinary collaborative efforts to dig deep into Grand Challenges-type problems, such a multi-disciplinary capstone senior design course

As the Engineering curricula are diverse and the needs of industry are ever-changing, incorporating these ideas will largely need to be done at the department level, beginning with a focused curriculum-level review. One approach might be for each department to create a Director of External Relations, or a position with a similar title. This rotating position, similar to other department-level directorships, would focus efforts in areas such as:

- Working directly with the Engineering Career Center to ensure our graduates have the best research and industry employment opportunities possible
- Polling industry representatives and alumni to determine what skills our graduates most need to have and working with the undergraduate and graduate committees as a contributor to department curriculum reviews
- Supporting student disciplinary society chapters to bring in speakers from the desired next career steps of the students
- Identifying opportunities to incorporate practical skills into the curriculum or into extra-curricular activities
- Teaming up with their counterparts in other majors, other WashU schools, and other universities to develop multidisciplinary efforts that support design thinking and collaborative projects

Success in this strategic initiative involves placing graduates higher in their chosen career paths and increasing SEAS' visibility among industries and top graduate programs.

In all of these initiatives, we are operating from a position of strength. We have top-notch researchers, as evidenced by our high rankings in faculty grant awards and publications. We have a commitment to teaching, as evidenced by the creation of the Teaching Professor position, the stated goals of our Dean, and a highly-committed Teaching Core. We have the excellent Teaching Center structure as a teaching resource for our faculty. And, we have the unique, growing, thriving St. Louis business, medical, and entrepreneurial community from which to draw important industry feedback and provide partnership opportunities for learning and working for our undergraduates.