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First-Year Engineering Program Curriculum ReDesign

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Howdy,

After 23 years in Telecom starting with building LD, internet, and email platforms and networks, I observed that the front line personnel that I was hiring didn't have what I considered to be skills that they should be bringing to the table. I began investigating why, and that led me to high school.

Alas, I began my journey in Education in 2010 inhabiting the classrooms of Lovejoy High School, where my two daughters attended.

I redubbed my PreCalculus course as Problem-Solving with Brooks and was also afforded the opportunity to lead an impactul Project Lead the Way (PLTW) Principles of Engineering (PoE) course which is a project-based learning survey of the engineering discipline.

Since the Summer of 2015 I have been privileged to work with the Texas A&M Sketch Recognition Lab (TAMU SRL) to evaluate a couple of online tutorial tools (Intelligent Tutoring Systems (ITS)) currently under development, Mechanix and Sketchtivity, that provide immediate constructive feedback to the students and student-level metrics to the instructors. I presented on this work at the state and national PLTW Conventions and at CPTTE in 2016.

I also spent 5 semesters beginning the Fall of 2015 taking online courses learning how to construct and deliver online courses. This resulted in a MSEd from Purdue University in Learning Design and Technology (LDT).

This widely varied background prepared me well for my next big adventure. Beginning in August 2018 I became the Texas A&M Professor of Practice for the Texas A&M Engineering Academy at Blinn College in Brenham. TAMU Engineering Academies are an innovative approach to providing the planet with more Aggie Engineers.

I am a technology learner and and engaged member of the TAMU IEEI (Institute for Engineering Education and Innovation).

My foundations were set by an upbringing on the family ranch near Joshua, Texas and 4 memorable years at Texas A&M where I met my wife, I led Bugle Rank #7 in the Fightin' Texas Aggie Band (Class of '86 Whoop!), and dove into Telecom Engineering. Once in Telecom, my learning continued at MCI, Vartec, and Charter.

Session 35080

First-Year Engineering Program Curriculum ReDesign

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Abstract

The accelerating evolution of student mindsets and industry needs is driving a revisiting of the structure of first-year engineering programs.

Following two years of swiftly parsing student performance results, instructor surveys, employer/recruiter feedback, and student evaluations, a new first-year, three-semester engineering student curriculum was deployed with skillset and content-knowledge objectives attuned to the future that lay ahead for engineering students.

The engineering leadership team chose to address the need for change using a deliberate "re-building strategy."[1] This choice involved invoking "a process oriented approach to the remaking of a curriculum…, involving external stakeholders. This applies sound systems engineering principles to the engineering curriculum itself."[1]

This paper documents the new design structure to include literature influencing the re-build. The study concludes with an exploration of a framework for addressing and managing the need to maintain an evolving curriculum going forward. Included will be a discussion of the challenges driving the need for a re-build as well as the evaluation of various options, some of which were not selected to be pursued at this time.

"The re-building strategy…is a fundamental change of academic view linking academia with societal context and needs…by emphasizing a shared set of values, identity and commitment. It is about educating engineers who will become change agents after graduation, with an understanding of stakeholder needs and the wider societal impact of engineered systems within the innovation process."[1] Although the need to re-build the curriculum was identified based on deficiencies, the desire to produce graduates equipped to impact society, or change agents, became the vision.

The previous first-year engineering courses were fully replaced by a feedback-driven reconstruct that immediately immerses incoming freshmen in a course focused on computer program design, algorithmic thinking, and problem-solving, using Python, with a weekly peppering of digital explorations of various engineering disciplines. Many of the lab assignments for this course involve developing code to address challenges encountered in their concurrent calculus course or subsequent physics course. All engineering students begin as general engineering students and follow the same course progression for their first three semesters before continuing into more specialized courses. The student may apply for acceptance to a specific major following a

successful second semester, yet they will continue with the third course in the common sequence whether or not they are accepted into a major.

Many students select engineering following counselor guidance referencing significant math and science capabilities, but the students often do not fully understand the myriad opportunities and rigorous cognitive demands that populate their chosen path. The discovery of this student naivety was the driving force behind the development of weekly online self-paced multimedia explorations to introduce the incoming freshmen to the many engineering options. Though currently organized by major, there is consideration of an adjustment to present whole industries each week while highlighting the variety of engineering majors working in those industries.

During the second and third semesters, the students move into a cross-curricular mode wherein the engineering course lecture and lab mirrors the concurrent physics course concepts such that lab activities are a practical, tangible demonstration of the physics concepts addressed in the classroom lessons. The engineering lecture is then a mixture of concept extensions and further application of the physics lessons as well as an opportunity to incorporate engineering ethics studies into the core engineering courses.

As further support of the tenets of the approach strategy, “the development of the new first-year engineering program at the University of Massachusetts Dartmouth began with a review of the education literature. The literature is consistent, and often overwhelming, in the following conclusions:

- Active and collaborative learning techniques can result in higher performance and longer information retention compared to the traditional methods.
- Integrating math, science, and engineering courses is an effective means to teaching students to deal successfully with cross-disciplinary problems.”[2]

The research data sources pointed increasingly towards the need to develop student programming and collaboration skills quickly to better prepare for the data processing and analysis demands of their upcoming courses and careers.

This study will explore the details of the proposed new structure supporting first-year, three-semester engineering with an inherent purpose of providing guidance for colleges assessing options for a first-year engineering curriculum refresh. The study concludes with a list of ongoing activities supporting the case that the maintenance of engineering curriculum requires the growth mindset of a lifetime learner.

Impetus

A six member committee comprised of three engineering professors, with expertise in electrical, mechanical, biomedical, civil, and computer science, and three science professors, with expertise in chemistry, physics, and math, convened during the summer of 2016 to investigate the source of a more than 30% failure/drop rate for students in the physics mechanics course. After identifying several contributing elements, they merged a proposed solution with many other student experience enhancements, which were already being considered, to drive a first-year experience curriculum rebuild. The committee came forward in March 2017 with recommendations to be implemented beginning fall 2018. This paper will focus on the recommendations, with reference to the challenges driving the change. A new study will be launched in the summer of 2021 exploring the impacts of the changes following the completion of the fall 2018 cohort's four year cycle.

Cahill, Ogilvie, and Weichold summarize that a cross-disciplinary team analyzed first-year student grades across multiple disciplines and found "that the pass rates of the ENGR courses were typically above 90%, while pass rates of the MATH and PHYS courses were typically between 70 and 75%."[3] As it was deemed early in the process that addressing the math challenges was a multi-year project, the college of engineering and the college of science worked jointly to strengthen the physics-engineering connection for the students. The immediate action regarding math was to more consistently enforce the calculus-ready confirmation standards and bolster the readiness test administration activities.

Accounting challenges were encountered regarding course hours, questions as to which college should house particular courses, and how to allocate funding. The analysis team chose not to minimize changes related to these topics due to negative impacts on the speed to deployment of the new curriculum rollout. Once a solution for improving retention was identified, an urgency to get new curriculum in place became the driving force for the project.

The investigation began during the summer of 2016, recommendations were provided in March 2017, and the new curriculum was delivered in the first courses in the fall of 2018. This timeline could not have been supported if numerous hours-allocation and funding-allocation approvals had been required. The engineering and physics faculty and staff worked closely to address the driving needs within existing structures.

Oregon State University undertook a similar evaluation of their first-year program in 2017 and began implementing a new design in fall 2020 with the following overarching guidance:
"The three core themes of the new curriculum will include:

- Engineering grand challenges and the Oregon State engineering student.
- Design engineering and problem-solving.
- Engineering computation and algorithmic thinking.

By engaging students in engineering challenges early in their academic journey, they will be better prepared for engineering coursework and more likely to graduate with an engineering degree."[4]

An ABET Issue Brief in fall 2017 shared the following summary of key curriculum impacts garnered from a review of engineering focus changes occurring at several schools at the time to include Rose-Hulman, MIT, and Rice.

"Six distinct themes — lessons learned — emerged as central to the design of effective and flexible engineering program design:

- The blurring of disciplinary boarders.
- Holistic approach to problem-solving.
- Informed by business.
- Customizable curriculum.
- Dynamic, hands-on learning.
- Effective assessment.

To remain relevant in the competitive higher education landscape and to effectively develop students who can meet the needs of today's global economy, university leadership must be thoughtful about how to get our students from here to there. A spirit of exploration, flexibility, innovation and experimentation must become a natural part of the learning process, and the delivery of education in general must be nimble enough to evolve as technology evolves."[5]

The curriculum redesign, as deployed, aligns well with the above findings in that there is a heavy focus on cross-disciplinary collaborative problem-solving in all three first-year courses as well as a vision to continue the evolution going forward to remain aligned with program and industry needs.

In an effort to identify those industry needs, an industry advisory group of engaged alumni is regularly queried, typically informally, regarding the needs they foresee as well as their observations of students as interns and employees. The ongoing general consensus has been that the students' technical abilities are sound and that developing their professional skills (e.g., communications, teamwork, and business and research writing) during their collegiate career needs more attention.

The New Design

A large southwestern university "solicited input from departments and engineering faculty on what was felt to be essential in a first year curriculum using a survey sent to department heads for dissimilation to their faculty and department curriculum committees. There was agreement that the math and science topics currently being taught were appropriate. The one item which faculty across the college agreed was necessary in the first year curriculum was computer programming."[3]

Engineering and physics faculty worked closely to adjust course and lab design towards a more project-based structure which included the development of custom lab equipment to better target the physical elements of the physics concepts presented in lecture.

While metrics around retention and science/math scores were the key drivers for the curriculum change, additional adjustments previously in discussion were also re-considered, such as the engineering ethics course. Only available for juniors or seniors, this course was often left until the final semester, while the students were interviewing for jobs, and administered jointly with the philosophy department. Consequently, many students did not internalize the lessons and found it challenging to apply the course material to their profession. The new design eliminates the stand-alone engineering ethics course and incorporates engineering-centric ethics lessons into the second- and third-semester courses as material solidly intertwined with their technical concepts.

The final aspect added was greater detail about the many engineering majors delivered every week as part of the first-semester programming course. Students often began their engineering program knowing only that they were good at math and science, yet not knowing what an engineering career entails. As students may apply for a particular major as early as completion of their second-semester courses, weekly lessons exploring one of the many offered majors was included as a component of their first-semester experience to drive informed decisions regarding choice of major.

The committee came forward in March 2017 with recommendations, which were immediately fast-tracked to support a fall 2018 rollout:

- The first-semester course in engineering, for all students, was a newly developed computer programming course using Python and integrated various calculus and physics evaluations as challenges in the programming lab.
- A weekly survey of an engineering major was added to the first-semester course curriculum.
- The second- and third-semester engineering courses, also new, tied directly to the concurrent physics courses, Mechanics and Electricity-Magnetism, with a focus on connecting physical engineering lab work to conceptual physics classwork.
- Physics coursework was reconstructed to become more engineering-centric.
- Physics grading practices were adjusted to focus on providing student feedback based on well-communicated learning objectives.
- Engineering Ethics was no longer a separate course as key engineering-centric case studies would be integrated into the second- and third-semester curriculum.
- Enforcement of completing the math prerequisite before being enrolled in the subsequent physics course resumed.

Preliminary responses to the change have been mixed as most first-year students have had no previous exposure to programming, so an initial course dedicated to this discipline has been a shock for many. The professors welcome the change and appreciate the closer tie to industry needs of computational thinking and a collaborative experience. Students from the two cohorts immediately preceding those moving to the new curriculum have guarded praise for the change, noting that the lack of programming and coding skills was a hindrance in their second year of study.

Future Evolutions

As the "focus in the course development process was on what the engineering departments felt the students should know (content), rather than on a course structure which was aligned with educational research on what methods work to improve persistence," each semester affords the instructors the opportunity to hone the lessons by applying techniques and activities from the evolving body of engineering education best practices.[3]

Portions of the second- and third-semester lecture materials were repurposed from the previous courses in the interest of time. Consequently the instructors are tailoring those lessons to incorporate more of their personal background knowledge and to best address their particular students' needs and interests each semester. With the speed of industry change, this adjustment will be ongoing resulting in the same lessons rarely fully repeated from semester to semester. A solid practice for an instructor is to target one lesson each semester and rebuild that lesson to increase student interest and engagement.

Though not widely deployed initially, beginning fall 2020, all students are enrolled in a zero credit hour student success course that addresses study strategies, life balance and wellness exploration, relationships, metacognition, and additional information on majors and careers in engineering. This course helps students make the transition from a secondary environment to the collegiate culture.

As mentioned previously, the hours-allocation and funding-allocation adjustment paths were not explored fully due to the time involved. There may be opportunities for efficiency in those realms, both financially and administratively. In addition, further evaluation of deeper cross-curricular work with the math department may yield benefits for all parties.

Many initiatives are still in development or being investigated relative to the college of engineering vision for the future:

- Create a pre-college online course to better prepare incoming first-year engineering students for the rigor of the coursework and challenges of collegiate life.
- Move much of the first-year success seminar information to a pre-college engagement.
- Create industry-focused information modules to introduce first-year engineering students to the career environments ahead.
- Incorporate more industry guidance and engagement into early college career programs for students, and adjust/enhance curriculum accordingly.
- Create a more robust feedback program from industry and former students to drive enhancements to the first-year programs and curriculum.
- Develop a strong mentoring network to ensure that each student receives solid personal guidance in both academic and career matters.
- Create a deliberate professional development program for the first-year engineering professors to better connect them with industry needs and curriculum adjustment opportunities. This may include summer industry work/research, or shadowing industry advisors.
- Include a required student course exploring the science of teaching and learning to set a foundation for the expectation that each student can effectively share their knowledge. This will help drive more students to STEM teaching roles.

A realization from refreshing the curriculum is that regular course updates and enhancements keep the course content relevant, and industry advising in the area of new hire expectations and the market vision should be the true drivers of design. Often a dive into a symptom leads to the larger issue which needs to be addressed which, in this case, was a more relevant first-year curriculum structure.

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Randy Brooks is in his third year as Associate Professor of The Practice with the Texas A&M University College of Engineering, Engineering Academy at Blinn College-Brenham. Previous to this appointment he taught precalculus and PLTW Engineering courses at Lovejoy High School, near Allen, Texas, after 23 years in various leadership roles in the Telecom Industry. Randy's research interests involve exploring Intelligent Tutoring System deployment and enhancing the secondary through first-year transition (academically, socially, functionally) for STEM students.