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A Pre-Baccalaureate Engineering Course for the Road Ahead

Randy Hugh Brooks, Texas A&M University

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 and 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 and M Professor of Practice for the Texas A and 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 and 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.

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A Pre-Baccalaureate Engineering Course for the Road Ahead

Randy Brooks
First-Year Engineering
Texas A&M University

Abstract

This paper explores what elements and concepts should be included in a pre-college, widely available digital course designed to better guide, inform, and prepare high school students interested in pursuing a career in engineering. The purpose of the course is to provide a digital tool for exploration by high school students and their advising network as they seek to gain a better understanding of what an engineering education and career entails. As the investigation has progressed, the potential benefit of developing separate courses for "guide and inform" and "prepare" is appearing. This paper will focus on the development of the comprehensive course with the understanding that there is potential for a separation by themes tuned to differing clientele as the vision evolves.

Impetus for this study is comprised of literature-based studies, peer and performance-evaluating administration observations, and my personal experiences regarding the chasm existing between (1) the understanding of engineering and the supporting knowledge and skills of the typical college of engineering-bound high school students, and (2) the level of knowledge and skill sets expected to exist in first-year college of engineering students by the college of engineering first-year professors.

My unique perspective and experience (bulleted below) has afforded me diverse front-line experiences involving a range of instructional differentiation practices required to address the varying levels of preparation observed in a wide array of engineering-bound students.

- Hiring recent college graduates for roles in Telecom for 23 years.
- Curriculum development and instruction of precalculus and PLTW (Project Lead the Way) engineering courses in high school for 8 years.
- Instruction and curriculum development for first-year and second-year engineering students at a large southwestern university.
- Informal college, course, and career guidance for secondary and early career college students.

The challenge to be addressed with this course is that each semester I observe that the majority of my students share that their parents, a neighbor, family members, or guidance counselors noted that they were good at math and/or science, and advised that they should study engineering. Thus, they are in my classroom, yet often not convinced regarding their pursuit of an engineering career. Often, they are not aware as to what such a career entails.

The primary goal of the course is to assist high school students with making a more informed decision regarding their selection to pursue engineering as a profession. A key secondary benefit is the potential concurrent education of high school student advising networks regarding what is involved in a career as a professional engineer.

Many students select engineering following counselor guidance referencing significant math and science capabilities, yet the students often do not fully understand the myriad opportunities and rigorous cognitive demands that populate their chosen path. Consequently, many first-year college engineering programs include weekly career opportunity explorations as part of their coursework to introduce the incoming freshmen to the many engineering options. Moving this student learning to a pre-college course would provide the student with greater clarity of direction, and reduce the first semester learning load.

Benefits of student completion of this course will be increased student retention and improved student performance. In addition, the widely available digital course will prove most beneficial to the underserved populations with previously limited access to much of the knowledge and skills incorporated into this pre-college course.

Included in this paper is a framework of concepts to be addressed in the course.

Content

Student skill and knowledge deficiencies are often observed in both academic preparedness and collegiate life readiness through instructor observations and student self-reflections. As such, items in these areas need to be part of a college prep program to ensure that students are readied on all fronts.

Radcliffe and Bos re-inforce that "key dimensions for building college readiness…include college knowledge, academic behaviors, and content knowledge" where college knowledge is "contextual skills and awareness" that comprise "the privileged information necessary to understand how college operates as a system and culture."[1] The transition from a secondary program to the collegiate culture structure is fraught with a significant increase in stress from learning new routines and exploring unfamiliar resources. Some students become overwhelmed, or ensnared, by the lifestyle change that often accompanies the move to college, even before academic challenges are encountered.

Culver and Bowman share that student success seminars "frequently take at least one of the following two forms: (1) orientation and academic success seminars that provide an extended orientation to campus resources available to enhance students' success in college, instruction in basic study skills, and/or a discussion of strategies to facilitate students' transition to college; and (2) academic inquiry-based seminars that ask students to practice higher-order thinking in small-group courses, which may be focused either on a single academic theme or a variety of academic topics based on the interests of students or faculty."[2] The course presented herein will gravitate

more towards the first form, although there will be elements of lesson extensions that reach into the second form.

Boetller, Goldfine, Leech, and Siegrist highlight an industry evaluation challenge in that "the differing results on the effectiveness of first-year seminars in positively contributing to retention and academic performance are not unexpected given that there can be significant differences in those courses that are designated as first-year seminars."[3] Student success seminars are still evolving significantly, and much of the challenge to their success is that the activities are occurring concurrently with the students' academic encounters and realizations. Benefits will be realized by having students internalize much of the same information prior to appearing in the college classroom on day one.

The need for student preparation is not new, though exascerbated by the accelerating pace of industry knowledge expansion and societal expectations. Studies from as early as 2006 highlight that "one of the major concerns of faculty is that students are underprepared for college classes. This theme persisted through faculty and advisor interviews and surveys. Faculty felt that a study skills program for all pre-tech students should be mandatory if student persistence was determined to be a goal of the college. In the area of academia, the student must be valued and made to feel a part of the college even before the school year begins."[5]

Student Success

Student success seminar courses are a collegiate reaction to help first-year students navigate the transition from the secondary environment to the higher education pathway. They primarily address life balance and academic study strategies. The student success course which I deliver covers the following topics. The class is designed such that students can perform any activities associated with the course during the one hour a week allocated for class. Many lessons involve delving into a particular topic and then having the students create a reflection as to how the topic plays into their lives.

- Study strategies
    - Consistent and regular (i.e., not the night before)
    - More self-managed study time, less class time
- Life balance/wellness
    - Social/environmental/emotional
    - Spiritual/physical/intellectual
- Relationships
    - Key actions to look for, and watch out for…
    - Be aware, alert, and engaged
- Metacognition
    - Teaching/learning strategies
    - Learning styles
- Exploring topics in majors of interest
    - Vision/passion
    - Career opportunities

The content is very pertinent to meeting student needs as many have not been prompted to think about these topics in their new environment. The common critique and feedback from my students regarding this course is that the content is coming too late. Students need this information and guidance before the first week of classes.

My observations support this critique as I see many students take heed of the lesson guidance and find themselves in a good weekly flow by the end of the semester. The detrimental issue is that there are often challenges not fully overcome in the first half of the semester that impact their overall grade in their courses, thus their achieving mastery may not be represented by their overall course grade.

Numerous studies support the benefits of such a course; we just need to deliver the content earlier. To apply a swimming metaphor, students need to know how to swim before they are in the higher education end of the pool. The content should be incorporated into an online college preparatory course that the student completes during their last semester of secondary school, or during the semester/summer before beginning their college career.

Internalizing this information prior to beginning college courses, as opposed to concurrent with those courses, allows the student the time to establish a framework for managing the upcoming life change. Removing the need to quickly acclimate to a new lifestyle and learning strategies from the first few weeks of school allows the student to focus more of their effort on understanding the academic concepts.

Technical Foundation

In addition to the life change, there are often academic deficiencies that drive a challenging level of differentiation required to teach first-year college courses. The chasm of knowledge and skills between students entering college and what is needed by employers is vast, and instructors often attempt to bridge that gap by speeding through a high volume of content during the first two years of college. This leaves the students with a thin layer of knowledge of many concepts as well as gaps where information was not internalized. Thus, there is a need for a technical college prep course for various majors. Here, I will address engineering, yet many of the topics cross all STEM courses of study.

The vision is that as students work through this course, their reflections and practice artifacts will be captured in an online journal that they may share with their first-year engineering professor to provide the instructor with some insight as to the knowledge and engagement levels of the incoming class. This could be as simple an artifact as information gathered in a Google Doc template, or an output from a LMS. Knowing which, and how many, students completed this course would inform instructor decisions regarding how to structure teams and provide detail regarding pre-knowledge from which to scaffold.

As part of a large southwest college of engineering study of student grades, Cahill, Ogilvie, and Weichold highlight the need to scaffold or reconstruct some math and science concept instruction where “analysis of student grades showed that the pass rates of the ENGR courses

were typically above 90%, while pass rates in the MATH and PHYS courses were typically between 70 and 75%."[4] The findings depicted here may be a challenge well-addressed by requiring a summer course re-enforcing key skills and concepts needed to be successful in all disciples explored as part of a first-year program.

Course Content

The target design for the college prep course mirrors a semester-long student success course of 16 classroom hours, such that the exercise could easily overlay the final semester of secondary school for the student.

The first five sections (College Operation) are grouped to build an understanding of and interest in the college environment ahead for the student to include an introduction to industry career options. The following seven sections (The Launching Point) build some foundational terminology and computational thinking skills as examples of the mindset that the students will encounter in college and career. The closing four sections (Transition to Career) provide more detail on careers, lifetime learning development, and a wrap-up of the course.

The course hourly breakout, by theme, is as follows:

College Operation

1. Overview of common college traditions and alumni/network contact importance.
    a. Walk through a day in the life of a college student.
    b. Discuss some common college traditions, and some not-so-common.
    c. Emphasize the importance of college student and alumni organizations.
2. Address college life such as balance/wellness, time management, and teamwork.
    a. Discuss the life change about to occur and how to prepare.
    b. Share some studying strategies within a time management structure.
    c. Note the importance of building teamwork skills.
3. Explore cross-curricular lesson design to heighten awareness and share strategies.
    a. Make connections across math, physics, and engineering courses.
    b. Re-inforce the importance of developing quality writing skills.
    c. Show how other subjects such as history, ethics, and musical improvisation may cross paths with or support engineering views and mindsets.
4. Overview of first-year engineering core/foundation courses.
    a. Share ABET student learning outcomes and expound on expectations.
    b. Conduct a detailed explanation of common course topics for first-year courses to include expected prerequisite knowledge.
    c. Identify support resources available to students.
5. Explore industry sectors, highlighting various majors involved in each.
    a. Link to many platforms with existing engaging documentaries.
    b. Identify key common foundations for engineering roles.
    c. Acquire or Create media of engineers relatings events in their careers.

The Launching Point

6. Explore programming using an interactive resource to include Google Colab for Python introduction.
    a. Build a programmatic thought foundation using myriad tools.
    b. Intro how to use programming to solve math challenges by thinking and coding.
    c. Develop engaging coding challenge activities for students to explore.
7. A Moment in Time, an intro to Statics.
    a. Start from the beginning with particle physics and forces.
    b. Teach moment analysis through to application.
    c. Introduce the basics of truss analysis with a focus on procedural thinking.
8. Explore digital supports.
    a. PhET is a solid source of physics concept simulations.
    b. Physicsclassroom.com provides lessons, often from alternate views.
    c. Hyperphysics.com is a visual sources of concept and equation applications.
9. Dig into some math application with derivatives and integrals.
    a. Connect calculus actions with engineering applications.
    b. Deep dive into graphic relationship of position, velocity, and acceleration.
    c. Spiral and expand previous programming action of math applications.
10. Build awareness of the engineering aspect of the tactile landscape to include buildings, roads, and supporting infrastructure.
    a. Connect the world around students to the engineering involvement in that world.
    b. Use some online construction games to encourage student exploration.
    c. Spotlight news stories with an engineering infrastructure aspect and ethics element.
11. How to build a phenomenal lab report and research paper.
    a. Deep dive into purpose and structure details.
    b. Provide exemplar reports for studies of interest to early career engineering students.
    c. Document pathway of lab report to research paper to funding to deployment.
12. Re-inforce electricity basics involving voltage (V), current (I), and resistance (R).
    a. Use PhET to support practices in this area.
    b. Use the online Arduino website to encourage electrical designs.
    c. Tie parallel resistance evaluation to rational functions in precalculus.

Transition to Career

13. Explore the careers of select engineers to highlight how the progression can flow.
    a. Focus on an inclusive gallery of engineers and activities.
    b. Scroll visuals to spotlight the vast reach of engineering roles.
    c. Describe the winding career paths on which many engineers look back.
14. Explore pedagogy practices to include the impacts of Metacognition and Learning Strategies.
    a. Guide student in a thinking about thinking exercise.
    b. Have students do a learning styles discovery survey.
    c. Create lesson around the science of learning.

15. Career preparedness to include “elevator pitch” and resume honing.
    a. Direct student to resume auto-critique websites and require resume product.
    b. Post exemplar resumes for student exploration.
    c. Post exemplar “pitches” and guide for student to build their own.
16. Review content covered in hours 1-15, and include a motivating and encouraging closer.
    a. Guided student review of their products.
    b. Guided student review of progress driving student reflection.
    c. Engaging closing activity and message.

There will be pre- and post-course assessments to gauge the immediate effectiveness of the course. As deployment progresses, metrics will be added to gather data from first-year engineering professors regarding student retention of content and benefit to their programs. There will also be student and professor surveys following the students’ first collegiate semester to evaluate performance impact and highlight sections to enhance, adjust, and add.

Restating, the purpose of this pre-baccalaureate course is to provide a digital tool for high school students and their advising network to gain a better understanding of what an engineering education and career entails while also building some base knowledge and skills for those students on the path to a college of engineering education.

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RANDY BROOKS

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 ITS (Intelligent Tutoring System) deployment, and enhancing the secondary through first-year transion (academically, socially, functionally) for STEM students.