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Student Success-focused Engineering College Preparatory Courses

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Howdy,

After 23 years in Telecom 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, 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. Texas A and M Engineering Academies are an innovative approach to providing the planet with more Aggie Engineers.

I am focused on enhancing the high school through first-year college experience and am an engaged member of the Texas A and M 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.

Student-Success-Focused Engineering College Preparatory Courses

Abstract

This paper explores the development of two distinct engineering college preparatory courses. A 10-hour "What's Up With Engineering?" course targets high school juniors and seniors that have some interest in, or have been directed towards, engineering as a career. A 16-hour "So, You're Going to be a(n) [School] Engineer…" course targets incoming first-year engineering students, and is customizable by school. The vision is asynchronous deployment accompanied by student creation in a digital journal.

Although the initial focus was to build a single course to address college and career readiness, "as the investigation has progressed, the potential benefit of developing separate courses for 'guide and inform' and 'prepare' is appearing" [1, p. 1], and that is the direction undertaken in this paper.

The former course will be largely deployed through a key contact point for college-bound secondary school students, the high school counselor and college recruiter networks. This channel is constantly under great strain with many students having myriad interests requiring support and would benefit from a solid, online, asynchronous course to inform both students and advisors about what an engineering career involves. The latter course will be driven through the particular college's new student conference program and acceptance letter matriculation processes.

"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" [1, p. 1].

My unique background and experiences (bulleted below) have afforded me a view of student and instructional challenges from multiple perspectives with an evaluation of skill needs across all fronts to include completing high school, completing college, and career success.

- 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/customization for first-year and second-year engineering courses at Texas A&M Engineering Academy at Blinn College-Brenham.
- Informal college, course, and career guidance for secondary and early career college students [1].

Observation has revealed many areas of opportunity regarding structure and content enhancement. Two of significance are the encouragement of student growth mindsets, and deliberate and targeted instructional (course) design in support of college preparatory needs.

There is a need to close the knowledge and skills gap for students entering college. Not all (and arguably not most) students have the opportunity of an impactful college preparatory program. Student opportunity is hindered by a lack of physical and academic resources as well as fixed mindsets. A solid college preparatory program needs to provide a space for students to acquire the base technical knowledge as well as the freedom and encouragement to embrace a growth mindset [2].

Two observations were the initial impetuses for these engineering preparatory courses: (1) many students entering my classroom were good at math and/or science, so their advising network suggested that they should study engineering (not bad advice, just not complete) yet they were unclear as to what an engineering career involved, and (2) the first course in the first-year sequence at Texas A&M is programming, and 65+% (in fall 2020) of the students entering my classroom had no prior knowledge of coding or programming.

“What’s Up With Engineering?” is designed to provide content to begin preparing high school students for the college environment while also providing targeted information as to what an engineering career entails. This course also has the potential to become a key tool in the high school counselors’ quiver of support tools. A high school student advising network educated on the details of an engineering career would prove quite impactful.

The primary goal of “So, You’re Going to be a(n) [School] Engineer…” is to better prepare incoming college of engineering students for both the environmental and academic challenges ahead. Much of the academic preparation in the courses is pre-teaching key concepts and developing supporting skill sets. A strong secondary benefit is to establish a clearly defined and easily accessible level of preparation expectations for prospective students and high school instructors to reference as they work in conjunction to prepare the student for early success in the college of engineering of choice.

This paper will discuss the case for such preparatory courses and document, in detail, the topics covered in each hour of both college preparatory courses. Course deployment strategies will also be described to include discussion of platforms and performance analysis opportunities. There will be no data collected related to this paper, although a working model will be constructed using the content map proposed herein. Actual deployment results, and related Institutional Review Board (IRB) actions, will be addressed separately as part of a more comprehensive study addressing the full spectrum of opportunities for enhancing the college and career preparatory process ranging from secondary school initiatives to completion of the second year of college courses. In this wider-view study, effectiveness will be measured using pre-assessments, mastery checks throughout the course modules, and post-assessments. Ideally, as deployment and reach of the college preparatory course continues to expand, collection of year-over-year and peer-to-peer student readiness evaluations by professors of the first-year students will be explored.

Among the metrics to be used to validate the expected benefits of successful students' completion of the courses through student and instructor surveys, student performance data collection, and in-course assessments, are:

- Greater student confidence in their career choice,
- Increasing first-year retention rates,
- Noticeable improvements in first-year college engineering student performance,
- Reduced knowledge and skill differential in first-year college engineering students,
- Progress towards expanding the quantity of incoming college engineering students afforded the opportunity for college preparatory support.

Beginnings

Although my move from industry to education was spurred by the lack of preparedness for operating in a front-line telecom engineering role that I encountered in candidates (college graduates) applying for open positions in my organization, my initial foray into the topic of college preparation was as a high school math and engineering instructor attempting to prepare my students for their step into college life. Students often return to their high school during mid-December following their first semester in college and I would regularly guide the conversation towards discussing how prepared they found themselves for that first semester. Although some did highlight deficiencies with their academic preparation, almost every student noted that they should have devoted more time to prepare for the challenges in addressing the social, emotional, and time management aspects of college life.

“Radcliffe and Bos, in a *Journal of Education* article, 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, p. 2], [3, p. 137].

Radcliffe and Bos then established the five goals listed below to drive the creation of the college preparation strategies that they put forth in their study. The college preparatory courses proposed in this paper focus on goals four and five with some level of goal three addressed indirectly. These are of an immediate need and provide a target toward which the Radcliffe and Bos strategies point.

Goals for a program to build interest in college and develop college readiness:

“The student will:

1) understand the nature of college,
2) recognize that a college education may be important to his or her future success,
3) gain positive perceptions and aspirations about college,
4) prepare academically for college admission, and
5) set short- and long-term goals that support becoming college-ready” [3, p. 137].

My subsequent move to a first-year engineering program professor in fall 2018 has given me a very clear view of the receiving side (where high school is the sending side) of the student transition to college. Aside from the academic and career decision challenges, there is the major life transition of collegiate life ranging from critical time management skills to be acquired to how to navigate the physical and digital social environments.

“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” [1, p. 2]. Following are the key topics that are addressed in a success seminar that I teach concurrently with my first semester engineer programming course—key strategies to understand, yet challenging to internalize while all the other ‘first college semester’ activity is competing for the students’ time.

- “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" [1, p. 3]

An overarching goal of the college preparatory courses is to increase student retention and persistence to graduation. "In order to improve retention of students and, ultimately, their persistence to graduation, institutions must determine which programs, policies, people, and other factors within an institution's control help students become more integrated into the social and academic culture of the university and to feel greater affinity for the institution" [4, p. 2]. These preparatory courses lay a foundation to support the integration, and begin the process of connection.

The implementation of college readiness programs continues to show solid results for their targeted deployments [5] [6] [7]. The challenge is that they are largely available to a small, targeted audience and are difficult to scale. The courses proposed herein strive to create a common student knowledge and skills foundation through an unrestricted inclusive deployment with scaffolding available, as deemed necessary, for the student.

Following are two sections with overviews of the material covered during each hour of both courses. Content selection was largely based on the recent curriculum rebuild and student success courses at Texas A&M followed by validation through a course catalog investigation of similar programs at a random sampling of colleges of engineering across the nation. In addition, a preliminary list of concepts and topics was shared with peers at the ASEE-Gulf/Southwest Conference in March 2021 with positive feedback that the list provided a good representation of common first-year engineering student base knowledge expectations. The paper then concludes with a proposed method for constructing, deploying, and managing the courses as part of a larger program going forward.

What's Up With Engineering?

The goal of this course is to provide detail as to what is involved in pursuing an engineering education as well as the subsequent career. The target audience is secondary students that are considering engineering as a major and career as well as anyone in the advisory role of such students such as school counselors, teachers, parents, family, or other influencers.

Following is the high-level instructional design hourly layout for the course [1]:

1. Explore industry sectors, highlighting various majors involved in each.
    a. Link to many platforms with existing engaging multimedia products.
    b. Identify key common foundations for engineering roles.
    c. Spotlight specific engineering actions in each sector.
    d. Acquire or create media of engineers relating events in their careers.
    e. Student product is a reflection about the sectors that appeal most to them.
2. Explore the 14 NAE Grand Challenges (GC).
    a. Description of each with an example of a solution being pursued.
    b. Students reflect and record their thoughts on groupings of 3-4 GCs.
    c. Student product is a passion reflection about the GC that appeals most to them.
3. Address college life such as balance/wellness, time management, and teamwork.
    a. Describe 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.
    d. Student product is their reflection on the top three strategies that they personally must develop to acclimate to college life.
4. Apply Engineering Design Process.
    a. Show a video of a team working through brainstorming and filtering on a particular topic.
    b. Show the prototype analysis from initial activity, as well as a second session of brainstorming on another concept.
    c. Highlight how engineering, science, and math interact and interrelate when pursuing a solution.
    d. Student product is student selecting from a provided list of needs and documenting their own brainstorming and filtering session.
5. Overview of first-year engineering core/foundation courses.
    a. Share ABET (Accreditation Board of Engineering and Technology) student learning outcomes and expound on expectations.
    b. Present a description of common course topics for first-year courses, to include expected prerequisite knowledge, and tie actions in those courses to the ABET outcomes.
    c. Student product is describing the most desirable ABET outcome to them, and why.
6. Explore programming using an interactive resource (Python IDE (Integrated Development Environment)).
    a. Describe importance of building a programmatic thought foundation while retaining creativity aspect.
    b. Intro how to use programming to solve math challenges by thinking and coding.

    c. Walk students through a sample first-year college programming course lesson to include providing an exemplar deliverable.
    d. Provide some engaging coding challenge activities for students to explore.
    e. Student product is their description of some code that they designed, and a multimedia view of the code in use.
7. Explore digital supports.
    a. PhET.colorado.edu is a solid source of physics concept simulations.
    b. Physicsclassroom.com provides lessons, often from alternate views.
    c. Hyperphysics.phy-astr.gsu.edu is a visual source of concept and equation applications.
    d. Student product is screen capture of some of students' products at PhET and key finds at the other sites.
8. Explore the careers of select engineers to highlight how the progression can flow.
    a. Share stories on an inclusive gallery of engineers and activities so that any student might see themselves in the lives of the engineers presented.
    b. Students scroll through many engineering-based snapshots with descriptions to spotlight the vast reach of engineering roles.
    c. Student product is a multimedia creation of an aspect that they found inspiring.
9. Explore specific engineering activities, and look to the future.
    a. Provide multimedia presentations of engineering feats, such as "Dream Big" to include their inception and impact.
    b. Share various perspectives regarding the future impacts of engineering, and guide the student to consider their role.
    c. Student product is a reflection about where they see themselves in this future.
10. Review content covered in hours 1-9, and include a motivating and encouraging closer.
    a. Guided student review of their products.
    b. Guided student review of progress observed in student reflections.
    c. Highlight key aspects of an engineering career.
    d. Review the academic challenges associated with an engineering degree.
    e. Engaging closing activity and message.
    f. Student product is a letter to their future selves describing their vision of their engineering career, or how this course has helped them discern that their passions are leading them down a different career pathway.

So, You're Going to be a(n) [School] Engineer?

The goal of this course is to prepare engineering students for the task ahead. Foundational academics are pre-taught, introductions to key elements and traditions of the school are made, and strategies are shared in regard to mental, social, and time management challenges that will be encountered in the collegiate environment. Significant time is devoted to items often covered in the student success courses as well as how to develop professional networks. Reinforcement of lessons in "What's Up With Engineering?" are deliberate in this module as revisiting the concepts further secures the foundational knowledge.

Following is the high-level instructional design hourly layout for the course [1]:

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 that are not-so-common.
    c. Emphasize the importance of college student and alumni organizations.
    d. Student product is a reflection on two items they learned in this section that they want to explore further.
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.
    d. Student product is a table/spreadsheet containing their weekly schedule to include classes, work schedule, study plan, and time allocated for sleep, meals, and social events. This is a first draft, so students may estimate items they don't know.
3. Explore cross-curricular lesson design to heighten awareness and share strategies.
    a. Make connections across math, physics, and engineering courses through examples of engineering analyses using both physics base principles and algebraic and calculus processes to validate findings. Establish the expectation that fundamentals from all three courses will overlap, often concurrently.
    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.
    d. Student product is a lesson design that includes exploring a concept across multiple disciplines.
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.
    d. Student product is a concept map tying the described course activities to the 7 ABET outcomes.
5. Explore industry sectors, highlighting various majors involved in each.
    a. Link to many platforms with existing engaging short documentaries.
    b. Identify key common foundations for engineering roles.
    c. Acquire or create media of engineers relating events in their careers.
    d. Student product is a concept map tying a major of interest to multiple industries or roles.
6. Explore programming using an interactive resource (Python IDE (Integrated Development Environment)).
    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.

    d. Student product is code for a program that the student produces with an explanation of the function of the code.
7. A Moment in Time, an intro to Statics.
    a. Set the foundation for particle physics and forces.
    b. Teach moment analysis through to application.
    c. Introduce the basics of truss analysis with a focus on procedural thinking.
    d. Student product is their work associated with the many practices in this section.
8. Explore digital supports.
    a. PhET.colorado.edu is a solid source of physics concept simulations.
    b. Physicsclassroom.com provides lessons, often from alternate views.
    c. Hyperphysics.phy-astr.gsu.edu is a visual source of concept and equation applications.
    d. Student product is a screen capture of a PhET product with a supporting explanation using resources at other sites.
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.
    d. Student product is stacked graphs of a p/v/a relationship using a student-produced cubic equation representing a physical object's movement, and a student analysis of the relationships.
10. Build awareness of the engineering aspect of the tactile landscape to include buildings, roads, and supporting infrastructure.
    a. Connect the world surrounding and visible to the students with 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.
    d. Student product is a description of the engineering elements of student-selected buildings/locations around campus.
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.
    d. Student product is student interpreting a simple lab and producing a lab report based on the guidelines shared.
12. Re-inforce electricity basics involving voltage (V), current (I), and resistance (R).
    a. Use PhET.colorado.edu to support practices in this area.
    b. Use the online Tinkercad Arduino website (tinkercad.com/learn/circuits) to encourage electrical product designs.
    c. Tie parallel resistance evaluation to rational function analysis in precalculus.
    d. Student product is their work associated with the many practices in this section.
13. Explore the careers of engineering alumni 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.
    d. Student product is a reflection on what they found most interesting regarding careers and roles presented in this section.
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. Show how a lesson is created using the science of learning.
    d. Student product is a reflection regarding how they think and how they learn.
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 students to build their own.
    d. Student product is a written "pitch" to share with others, and their current resume after editing based on the information shared in this session.
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 the progress seen in their student reflections.
    c. Engaging closing activity and message.
    d. Student product is a reflection of their progress through the course, what they want to explore more, what they need to spend more time on in order to best prepare for the college of engineering adventure, and what they are most excited about regarding the particular college.

Next steps, toward the bigger picture

The primary software tool for construction of both courses will be Articulate. Each course will be prefaced with a section to include a course overview and purpose, student learning objectives, and a guide regarding management of the digital portfolio, which the student will create to house their many reflections, practices, and products. Evaluation of the optimal course hosting platform is ongoing. The courses will be hosted in a LMS capable of supporting progress tracking, ITS (Intelligent Tutoring System) tools, and student portfolio production needs. Although the courses will be built with a lesson sequence, students will be free to determine the pace and order at which they will complete the course. With availability to a wide-range of users as a guiding principle of these college preparatory course productions, the courses may need to be hosted in multiple venues.

Initial deployment will be managed through a targeted collection of secondary school guidance counselors and a subset of students admitted to a university engineering program. Feedback from that initial deployment will drive enhancements to be incorporated in subsequent, and more expansive, distributions of the products (courses).

As referenced previously, these college preparatory courses are an integral and foundational element of a larger enhancement strategy for the secondary school to first-year college engineering transition space. To build on the benefit of the pre-teaching activity provided by these college preparatory courses, college instructors will need to "stimulate recall of prior learning" (Gagne event number 3) [8, p. 248] in their lessons. Further reinforcement occurs with the embedding of basic skills development in the college curriculum [9]. Looking to the other side of the transition, high school instructors should look for the opportunity to tie elements in their lessons to the future 'needs' highlighted in these college preparatory courses.

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