Work in Progress: Impact of Exposure to Broad Engineering on Student Perceptions

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Introduction & Motivation

This work in progress paper primarily serves to introduce the structure and approach of a recently redesigned online course for undergraduate engineers. Future work to expand upon this initial exploratory paper is expected. The course aims to provide exposure to a wide variety of core topics, as well as help students understand the "broad" skills required for success in their future engineering careers. The content of the course is continually evolving based on observations of student perspectives, updated trends in the engineering field and broader world, and specific student feedback. The modular, online nature of the course allows for continuing evolution.

The course redesign was informed by a desire to explicitly incorporate a Broad Engineering perspective by exploring the diverse challenges engineers will face in the 21st century and examining the knowledge, skills and abilities required to meet these challenges. This broad perspective is analogous to the horizontal bar of the T-shaped skills model introduced by David Guest in 1991 [1]. The concept of the "T-Shaped" Engineer is concisely explained in Rogers and Freuler [2]. The value of broad engineering was recently reaffirmed by students themselves. The TUEE Phase II report [3] just released by ASEE summarizes student suggestions on ways to improve engineering instruction. "Participating students concluded that their institutions were paying insufficient attention to multiple KSAs [Knowledge Skills and Abilities] needed to produce the desired T-shaped professional – one who possesses deep expertise within a single domain, broad knowledge across domains, and the ability to collaborate with others in a diverse working environment."

Instructional Context

A required undergraduate-level technical management survey course at the Missouri University of Science and Technology, consisting of ~75% mechanical engineering majors and ~89% males, was redesigned to expand the overall course goals while maintaining coverage of core topics. The course serves undergraduate mechanical engineering students as a core graduation requirement, and also reaches other majors such as geological engineering, metallurgical engineering, aerospace engineering, and more. Typical course composition includes approximately: 3% freshman, 37% sophomore, 25% junior, and 35% senior level students. The one-credit hour course does not have any prerequisites, so some students choose to participate early in their academic career while others complete the course in their final semesters. Reaching such a diverse student audience is a challenge, as the student population is not only diverse in terms of academic major and level in school, but also maturity, work experience, etc. The course is currently offered each semester (fall, spring, summer) and reaches 450+ students each academic year. The course exists to introduce topics relevant to the technical manager in the 21st century. Core topics historically covered in the course include: management practices, leadership, communications, project management, working in the global environment, risk management, systems engineering, product development, entrepreneurship, ethics, and quality management.

As part of a campus-supported course redesign effort, this high-enrollment course was converted to an online format in 2014. Prior to the redesign, students participated in a traditional, classroom-based lecture format of the course delivered in a large lecture hall with capacity of approximately 100 students per section. With the redesign, an alternate fully-online version of the course was made available to students. Student acceptance of the new format facilitated a transition to the current fully-online delivery of the course for all students. The general form of the online course involves content structured in "modules" organized by topic, with one module per week delivered in a regular fall or spring semester. (Summer offerings of the course continue with the module format, but coverage is accelerated to include two modules per week.)

All content is presented through the campus learning management system, with no textbook required. All course resources are either openly available online (open education resources[OER], TED™ talks, etc.) or have been created specifically for the course by the instructor or other subject matter experts. Further, live virtual guest speakers are periodically incorporated. The use of open and/or custom created resources is an obvious economic benefit to students, but also allows the instructor to easily customize and update the course. Each week, students engage with print and/or video content through the learning management system and submit a variety of graded works. Weekly assignments vary by module, but a typical module may include a quiz, group discussion and self-reflection assignment. Additional detail of module content and structure will be presented in the next section.

The updated course continues to cover core topics, with additional emphasis on how those topics relate to the challenges engineers will face in the 21st century. Students are exposed to visions of our world in future decades and tasked to explore the National Academy of Engineering's 14 Grand Challenges for the 21st Century [4]. They are then asked to evaluate their individual strengths and weaknesses relative to the knowledge, skills and abilities identified by ASEE [5] and NSF [6] as critical for success as a 21st century engineer. Throughout the semester course, students are tasked to explore topics that reinforce a broad perspective of engineering, well beyond the purely technical, including; cross-cultural communication challenges, ethical dilemmas in modern engineering, entrepreneurship and the maker movement, social responsibility of the profession, the human elements of project management, etc. As topics are presented, students are required to discuss opposing perspectives, reflect on their own aspirations, and ultimately identify opportunities for personal growth and further learning.

The course goals are communicated to students in an introductory Module 0. The course goal(s) are stated as follows. Students will: 1. Identify the key knowledge, skills and abilities (KSAs) required for engineering success in the 21st century, 2. Explore relevant professional and technical topics, 3. Evaluate their own individual strengths and weaknesses relative to qualities demanded of future engineers, and 4. Identify areas for personal growth and opportunities for further instruction. Each course module addresses specific learning objectives that support the overall course goal.

Module Summaries

This section will present a summary of select course content, but does not attempt to enumerate all topics covered in the course. All modules, and their corresponding learning objectives, serve to support the overall course goal. Reference to broad engineering skills (i.e., KSAs) and student self-reflection on strengths and opportunities for growth are incorporated within each topic-related module. Additionally, specific modules at the outset and end of the course serve to introduce the significance of KSAs and allow for student reflection, respectively.

At the outset of the course, the course goal and specific professional and technical topics to be covered are presented to students, along with a general course orientation and individual introductions. (Though approximately 220 students participate in the course at once, students are divided into groups of approximately 15 students for collaborative assignments like discussions. In this manner, classmates can get to "know" one anther through repeated course interactions.)

In the first content module, students begin to explore their role in the future of engineering. Module 1 learning objectives are as follows: 1. Explore several expert predictions about our global future in the next century. 2. Critique those predictions and compare them to your own view of the future. 3. Recognize the grand challenges that future engineers will need to solve. 4. Identify individual qualities the 21st century engineer must possess. The content and activities associated with this module typically include:

- Readings and videos exploring expert visions of our future world (i.e., population growth, environment, technology in 2050)
- Readings exploring the future of engineering – NAE Grand Engineering Challenges [4] and predictions from The Engineer of 2020 [6]
- Readings exploring ASEE TUEE Phase 1 results [5], including top 15 high priority KSAs
- Quiz to assess basic understanding of future visions with student critique
- Written reflection on the one NAE Grand Engineering Challenge they want to tackle, and associated KSAs needed to contribute to this challenge.
- Group discussion based on current news (autonomous vehicles/driverless cars)

Throughout this module students are presented visions of the future, and their role as engineers in that future, that are especially broad and multidisciplinary. Future engineering work is portrayed as involving increased complexity, global interconnectivity, seamless integration of technology, multidisciplinary competence and the like. In summary, students are shown the importance of the "T-shaped" skills that will be necessary in their future.

The next content module expands on those ideas, and tasks students to reflect on their own strengths and opportunities for growth relative to the broad skills needed in their future. Module 2 learning objectives are as follows: 1. Identify individual strengths and opportunities for growth relative to the attributes required of the 21st century engineer. 2. Explore your personality type and preferences. 3. Assess your preparedness to meet the required qualifications and responsibilities associated with a specific engineering job. The content and activities associated with this module typically include:

- Review of top 15 high priority KSAs
- Written self-assessment of strengths and opportunities for growth relative to KSAs
- Readings and videos exploring basics of personality type (Myers Briggs™ and Big5™)
- Written reflection on personality type results, exploring individual preferences and encouraging self-awareness
- Group discussion based on current news ("broad" skills valued by Google™)

Once students have explored the first two modules, the course shifts to coverage of core topics. (Core topics are outlined in the Instructional Context section above.) Core topic modules, and their corresponding learning objectives, continue to support the overall course goal. Reference to broad engineering skills and student self-reflection are incorporated within each topic-related module.

One sample core topic module focusing on intercultural communication is summarized here. Learning objectives are as follows: 1. Explore challenges associated with intercultural communication. 2. Identify culture dimensions and their effect on business communication. 3. Compile a cultural brief to help prepare for successful global interactions. The content and activities associated with this module typically include:

- Readings exploring Hofstede's framework of six culture dimensions
- Videos exploring (sometimes comical!) examples of intercultural communication pitfalls
- Group discussion including self-reflection on cultural awareness, past experience and opportunities to develop weaknesses
- Written cultural brief (memo to prepare coworkers for business trip to foreign country)

Ten to twelve additional topic modules exist in the current course progression, with one topic module addressed per week in a typical semester. The modules may be reordered and/or utilized as stand-alone lessons in other classes as desired. For instance, the module on project management could be inserted in a design class or ethics module added to any engineering course. Sharing with other instructors within the same institution is readily accommodated through features of the learning management system.

A final culminating module inserted at the completion of the course encourages students to reflect on what they have learned and plan for continuing growth in broad, "T-shaped" skills. Learning objectives are as follows: 1. Revisit your individual strengths and weaknesses. 2. Prepare a plan for lifelong learning growth. The content and activities associated with this module typically include:

- Readings exploring the value of lifelong learning and links to open resources (edX™, Udacity™, MIT OpenCourseWare™, Coursera™, etc.)
- Written reflection on top three areas for continued growth (KSAs or other) and plan to develop

Quantitative Perspectives

Traditional quantitative measures such as student assignment scores or pre- and post-course assessment of topic-related knowledge are of little value to understanding the impact of exposure to the broad perspectives and T-shaped skills presented in this course. The course goals are met by successful completion of individual tasks within each module, as module learning objectives support the course goal. With few exceptions, students conscientiously complete all assigned tasks and consequently achieve the learning objectives of each module. In other words, all students who put forth reasonable effort can be "successful" in the course and meet learning objectives. (Typical course grade distributions result in 3% of students receiving D/F grades, and 10% in the C/D/F range. Low grades are almost always the result of missing and incomplete assignments.)

This work in progress paper attempts to present only limited initial exploratory survey data, with focused longitudinal studies presented in future work. An exploration of student "areas for continued growth", as self-identified by students in the final course module, offers some insight into the impact of exposure to the broad, T-shaped topics. Students were asked to consider the skills they feel they need to be successful in their future engineering career and identify the three KSAs they need to continue to develop. In other words, students identified their top three areas for personal growth from the TUEE Phase1 15 high priority KSAs. The graph below tallies all responses for the Fall 2017 section (n=219 students).

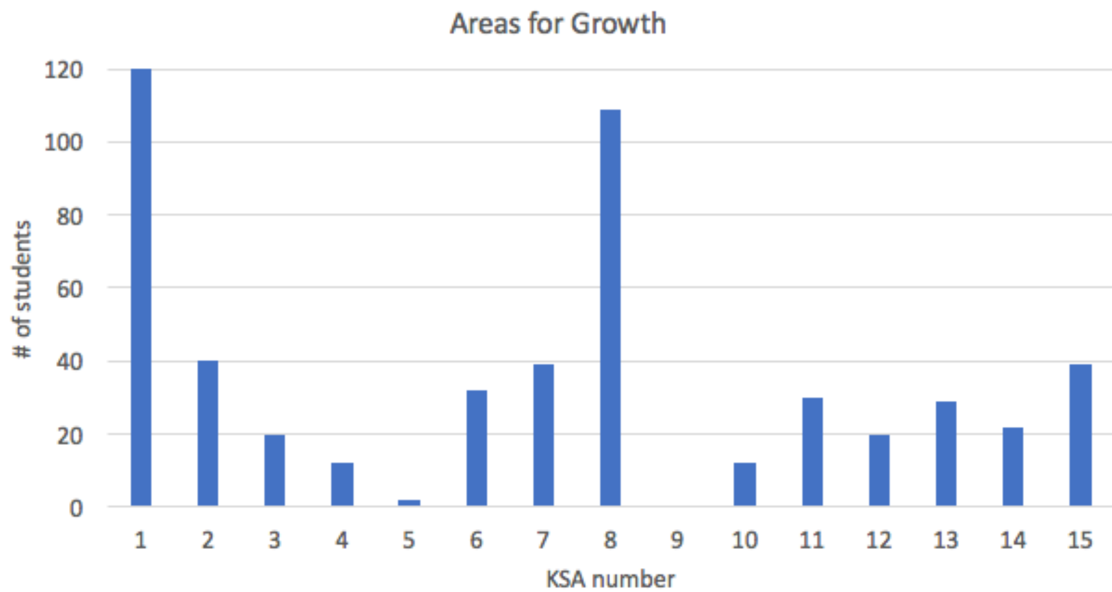

Figure 1
Top 15 High Priority KSAs

1: Good communication skills (skill)
2: Physical sciences and engineering science fundamentals (knowledge)
3: Ability to identify, formulate, and solve engineering problems (skill)
4: Systems integration (knowledge)
5: Curiosity and a persistent desire for continuous learning (skill)
6: Self-drive and motivation (ability)
7: Cultural awareness in the broad sense (nationality, ethnicity, linguistic, gender, sexual orientation) (knowledge)
8: Economics and Business Acumen (knowledge)
9: High ethical standards, integrity, and global, social, intellectual and technological responsibility (ability)
10: Critical thinking (skill)
11: Willingness to take calculated risk (ability)
12: Ability to prioritize efficiently (skill)
13: Project management (supervising, planning, scheduling, budgeting, etc.) (skill)
14: Teamwork skills and ability to function on multidisciplinary teams (ability)
15: Entrepreneurship and intrapreneurship (ability)

As students were asked to consider the skills they felt they would *need to improve to be successful in their future engineering career*, the "Areas for Growth" indicate both the students' perceived *value/importance* of the KSA and individual *need to improve* in that area. In other words, students identified the area as important and needing more work! It is interesting to note that students identified "1. Good communication skills" and "8. Economics and Business Acumen" as top areas for growth. Recall the class composition includes ~84% mechanical engineering students. Identification of these T-shaped skills is an encouraging indicator that students understand the value of a broad engineering education.

A wealth of other data, complied through course submissions and specific survey instruments, is available for further analysis. A very limited perspective is offered here. Specific research questions will inform further exploration of current data and collection of additional quantitative data.

Qualitative Perspectives

Student submissions throughout the course, especially analysis and opinions presented within module discussions, highlight a strong acceptance of the value of broad, T-shaped skills. Similarly, comments included in the final module's self-reflection offer encouraging qualitative perspective. A small selection of anecdotes from students include:

> I'm not good at public speaking and dislike it. Just because I don't like something doesn't mean I can ignore it.
>
> My general knowledge and awareness of the business and engineering world has grown. There was a lot in this course that I never really thought about before.
>
> My biggest take away from this class is that soft skills are a very important part of your success and you need to develop them.
>
> There is always room for improvement in soft skills…from this course, I have learned about corporate culture, personal growth, professional responsibilities, useful project management techniques, and property rights. I have already begun using the project management knowledge for my design team.
>
> From this course, I realized that culture awareness is very important. I never realized how important it is in the field of engineering until going through this course. This course also made me realized that much of the skills needed to be great engineers could only be gained with experiences. This made me excited for the future, to learn from others and to share knowledge with others.

Future Work

While this paper presents only preliminary, exploratory survey info and course structure, future focused research is planned. The authors are especially interested in exploring the potential impact this course may have on persistence in engineering, especially for women and underrepresented minorities. As the class reaches over 400 students per year, the potential for impact is great. The course, as currently delivered, includes coverage of "broad" and "T-shaped" engineering topics and their connection to students' individual goals and strengths. The work of Matusovich, Streveler and Miller [7] offers a framework for how and why students persist in engineering. Their research supports the belief that faculty can encourage students to persist in engineering by exposing them to a broad perspective of engineering careers and roles, and by facilitating the connection of an individual student's skills to the diverse roles engineers will play in our 21st century world. Additionally, the AAUW report Solving the Equation [8] found that: "By emphasizing the wide variety of expertise necessary to be a successful engineer or computing professional—including less stereotypically masculine skills such as writing, communicating, and organizing—college engineering and computing programs can help young women see engineering and computing as fields in which they belong." These works, among others, indicate the potential of this course to have a positive impact on persistence – especially for those who may not identify with the typical engineer stereotypes.

Further exploration of student values and attitudes about the role of engineers, individual motivation to pursue engineering, and traits of successful engineers may be surveyed after exposure to the Broad Engineering perspectives in this course. Trends may be evaluated to explore shifts in attitude and perception – especially those that may encourage persistence in engineering. Course content modules may be tailored to specifically address certain aspects, like emphasizing how "broad" skills (beyond the traditional technical math/science) "fit" with the diverse roles engineers will play in the 21st century and beyond.

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