122nd ASEE Annual Conference & Exposition
June 14 - 17, 2015
Seattle, WA
Seattle Making Value for Society
Paper ID #11576

The ”T-Shaped” Engineer

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Rogers joined the university in October, 2008 bringing with him 35 years of industrial experience. His career includes senior leadership roles in engineering, sales, and manufacturing, developing products using multidisciplinary teams to convert customer needs to commercially viable products and services. He brings this experience to the university where he leads the effort in developing experiential, multidisciplinary learning.

Rogers co-developed the ABET approved year-long Capstone design experience. With a focus on providing students with a broader experience base, the multidisciplinary program applies teams of engineers, business, design, and other students to work with Ohio companies to help them be more competitive and with local non-profits to help them become self-sustaining. Using a formal design process, teams develop new products to meet industries' competitive needs or those of people with disabilities. Students learn to solve open-ended problems and gain skills in critical thinking, professional communication, ethics, and teamwork. Rogers recently expanded this one-year program to a four-year Integrated Engineering and Business (IBE) honors program.

Rogers earned his PhD at the University of Massachusetts, Amherst focused on Mechanical Engineering and Manufacturing and holds the position of Professor of Practice at The Ohio State University.

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Richard J. Freuler is the Director for the Fundamentals of Engineering for Honors (FEH) Program in the OSU Engineering Education Innovation Center. He teaches the two-semester FEH engineering course sequence and is active in engineering education research. He is also a Professor of Practice in the Mechanical and Aerospace Engineering Department and conducts scale model investigations of gas turbine installations for jet engine test cells and for marine and industrial applications of gas turbines at the Aerospace Research Center at Ohio State. Dr. Freuler earned his Bachelor of Aeronautical and Astronautical Engineering (1974), his B.S. in Computer and Information Science (1974), his M.S. in Aeronautical Engineering (1974), and his Ph.D. in Aeronautical and Astronautical Engineering (1991) all from The Ohio State University.

The "T-Shaped" Engineer

Introduction

Global change creates competitive pressures for U.S. industry, generating the need for an ever-increasing level of broadly-educated engineering students entering the workplace. This notion has been communicated through the NAE [1] and more recently by ASEE's "Transforming Undergraduate Engineering Education [2] (TUEE)" workshop where industry and academic participants “seek a T-shaped engineering graduate who brings broad knowledge across domains and the ability to collaborate within a diverse workforce as well as deep expertise within a single domain”. These and other industry feedback encourage us to rethink the way we deliver engineering education. Recent engineering graduates continually find themselves learning on-the-job business acumen, struggling with open-ended problem solving, working for perhaps the first time on multidisciplinary teams, and learning how to communicate within and outside the organization. Many companies respond to these challenges by investing in multi-year training programs for new hires to augment engineering education with a broader set of skills.

To better prepare students for these rapidly changing industry needs, The Ohio State University (Ohio State) developed and now offers a recently-approved multidisciplinary undergraduate honors program—combining engineering and business students in an integrated four-year curriculum. Students in the Integrated Business and Engineering (IBE) Honors program study and work as a cohort throughout their undergraduate experience. They supplement their standard curriculum with core courses of the complementary degree and take a sequence of dedicated IBE courses and seminars focused on experiential, entrepreneurial, and multidisciplinary learning. Student teams apply classroom theory and tools to real-world practice and open-ended problem solving. The program provides each student the opportunity to develop the professional tools and skills required to meet today’s global challenges—preparing them to make significant contributions to industry immediately upon graduation. IBE students are better prepared to migrate to leadership positions and to understand the management challenges to compete in our global economy. Industry partners interested in interfacing early on with our top students contribute to the program by counseling on curriculum design, hiring interns, sponsoring cornerstone and capstone projects, holding in-class workshops, and participating in professional development activities.

The IBE program recruits a small percentage of business and engineering honors students accepted at Ohio State each year. The curriculum is not for the faint of heart. Students must maintain a 3.5 GPA throughout the four years, and those entering college with substantial advanced placement or post-secondary option credit toward their degree are the most likely candidates to succeed. IBE students finish with a bachelor's degree in their home program, a minor in the complementary program, and diploma recognition for completing the IBE Honors program. Effectiveness of the program is currently measured qualitatively by the overwhelmingly positive feedback from hiring companies and internal summary reports on the first two cohorts. Research to develop authentic assessments of professional skills is currently underway and will be ready to assess the first graduates of the program in spring 2017.

The Need

National leaders are calling for improved preparation of engineering graduates to address the great challenges of this century [1] [3]. ABET's outcomes-based accreditation requirements define specific student outcomes that span technical and professional preparation [4]. Feedback from engineering programs indicate that curricular changes are being made in response to ABET requirements, giving greater attention to effective communication, teamwork, modern engineering tools, and design [5]. Based on this study, over 90 percent of employers consider new engineering graduates adequately or well prepared to use math, science, and technical skills. However, they find inadequate preparation in problem solving (20%), communicating and working in teams (25%), and understanding the culture in which they work (50%).

The American Society for Engineering Education's (ASEE's) recent workshop on Transforming Undergraduate Engineering Education (TUEE) further details knowledge, skills, and abilities (KSAs) required for engineering practice [2]. Unacceptably high percentages of graduates are judged fair or worse in achieving important KSAs: project management (77%), economics and business (90%), teamwork (55%), decision making (76%), curious learner (53%), critical thinking (58%), and several others. Only 9 of 21 KSAs showed good or very good preparation in 50% or more of graduates. Clearly, engineering graduates are not being prepared consistently in KSAs needed for success.

The topic of T-shaped engineering has become so prevalent that Michigan State University hosts a yearly summit specifically on this topic. The 2015 T-Summit [6] includes such relevant topics as:

- Higher education and employer partnerships that develop T-shaped competencies
- Employer practices that advance T-shaped competencies
- Higher education partnerships that promote T-shaped education
- Metrics and competencies that define the "T"
- Cultivating entrepreneurs and innovators

In Oregon, the Engineering and Technology Industry Council (ETIC) commissioned a 2013 study [7] of Oregon technology employers to assess the importance of various technical and non-technical skills, and the level of satisfaction with these skills in recent graduates from Oregon's engineering programs. Designed and administered by the Oregon University System Office of Institutional Research, the survey was distributed to engineering hiring managers, CEOs, and other senior executives, and human resources professionals from technology-related firms throughout Oregon. A total of 286 responses were received, representing a wide range of industry sectors around the state.

This survey's most striking finding is the wide gap between high level of importance and low level of satisfaction with Oregon engineering graduates in skills and attributes associated with T-shaped professionals, including:

- Written communication
- Getting things done in a complex environment
- Verbal communication
- Client interaction skills

The rapid transformation of the Chinese society calls for changes to engineering workforces and a transformation of current engineering education. This paper [8] introduces a new workforce called the T-shaped engineer which is embraced by both the academic and industrial field. This new profile is generally defined as a broad learning (top bar of the T) and a deep understanding of engineering concepts (vertical branch of the T). Specifically, there is a call for sweeping structural and cultural changes in engineering education, including:

- A shift from disciplinary thinking to interdisciplinary approaches
- Increased development of teaming skills
- Greater consideration of the social, environmental, business, and political context of engineering
- Improved student capacity for life-long learning
- Emphasis on engineering practice and design throughout the curriculum

Nearly one third of Chinese college students are studying engineering [8] and great strides are being made but many challenges persist. Future changes in engineering curriculum include ethics to develop independent personalities with good quality and character while forming correct views of the world, life, and the value system. Additional changes include logical thinking, interpersonal communication skills, and extra-curricular activities including industrial internships.

A recent survey [9] by the Association of American Colleges and Universities (AACU) show a significant difference in perception between the views of students and industry regarding the students' preparation and readiness for the work force (Figure 1).

"When it comes to the types of skills and knowledge that employers feel are most important to workplace success, large majorities of employers do not feel that recent college graduates are well prepared. This is particularly the case for applying knowledge and skills in real-world settings, critical thinking skills, and written and oral communication skills — areas in which fewer than three in 10 employers think that recent college graduates are well prepared. Yet even in the areas of ethical decision-making and working with others in teams, many employers do not give graduates high marks," the AACU report says.

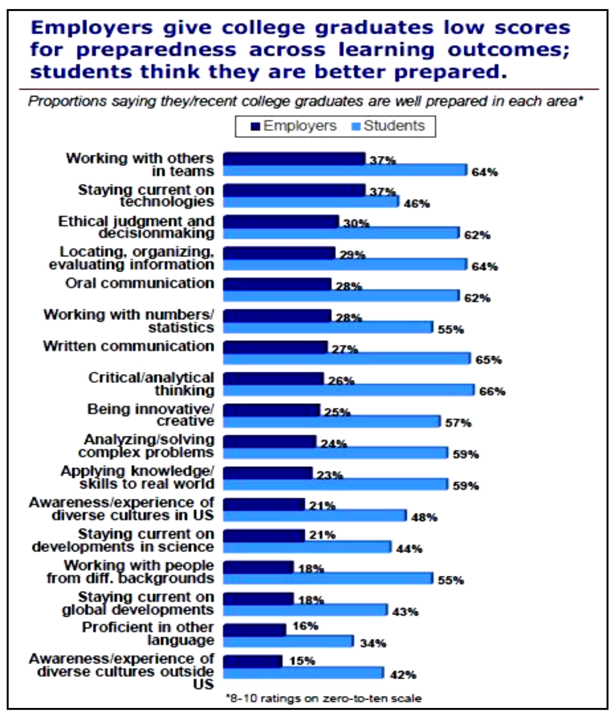

Figure 1 AACU survey of student preparedness *[9]*

Parts of the employer survey help support the need for curriculum change including the introduction of T-shaped engineering broad skills. Sixty percent of surveyed employers agree that new hires should have both specific skills and a range of knowledge. Other results found large majorities of employers supporting the notion of general education and curriculum extending beyond job training.

So, what is a T-shaped Engineer?

The term was first conceived by David Guest in 1991 [10] and popularized by Tim Brown, CEO and president of IDEO, a prominent product design firm in California. CEO Brown [11] says, "We look for people who are so inquisitive about the world that they're willing to try to do what you do. We call them T-shaped people. They have a principal skill that describes the vertical leg of the T — they're mechanical engineers or industrial designers. But they are so empathetic that they can branch out into other skills, such as anthropology, and do them as well. They are able to explore insights from many different perspectives and recognize patterns of behavior that point to a universal human need. That's what you're after at this point — patterns that yield ideas."

According to the organizers of the T-Summit [6], "Currently higher education is producing I-shaped graduates, or students with deep disciplinary knowledge. T-shaped professionals are characterized by their deep disciplinary knowledge in at least one area, an understanding of systems, and their ability to function as adaptive innovators and cross the boundaries between disciplines.

Figure 2 T-shaped professional *[6]*

The two halves of the vertical bar of the "T" (Figure 2) represent the disciplinary specialization and the deep understanding of one system. Systems describe major services, such as transportation, energy, education, food, and healthcare, that impact quality of life. These systems are comprised of interconnected components of people, technology, and services. To understand a system, one must know how it functions from the bottom to top in order to address challenges.

The defining characteristic of the T-shaped professional is the horizontal stroke, which represents their ability to collaborate across a variety of different disciplines. To contribute to a creative and innovative process, one has to fully engage in a wide range of activities within a community that acknowledges their expertise in a particular craft or discipline and share information competently with those who are not experts."

The Kern Family Foundation is helping engineering schools change their pedagogy to develop the entrepreneurial mindset in undergraduate engineers [12]. The Kern Entrepreneurship Engineering Network (KEEN) consists primarily of small private engineering schools to promote this change. Attributes of the KEEN entrepreneurially minded engineer are integrity, tenacity, ethics, creativity, intuition, a deep knowledge of engineering fundamentals, the ability to engineer products for commercialization, a penchant for lifelong learning, an ability to see how his or her ideas fit into the larger context of society, and proficiency in communicating his or her ideas. Referring to Figure 3, the KEEN pyramid consists of three levels of engineers and four cornerstones including technical fundamentals (vertical bar of the T) and customer awareness, business acumen, and societal values (representing the horizontal bar of the T). While not specifically defining their entrepreneurially minded engineer as T-Shaped, their concepts include the need to broaden the traditional engineering mindset.

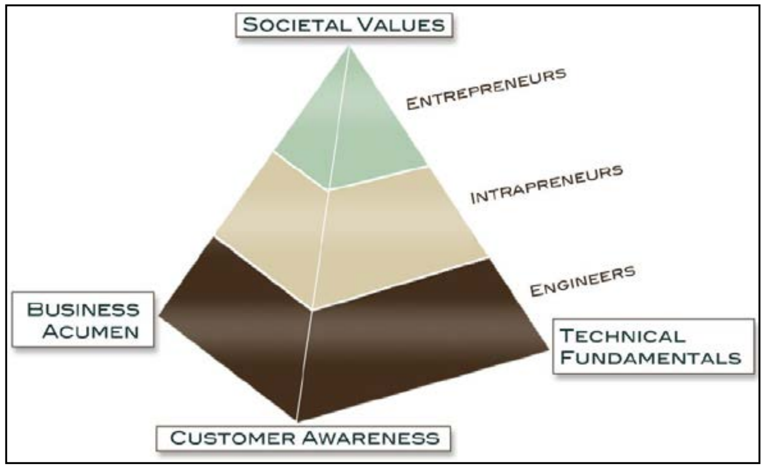

Figure 3 KEEN entrepreneurial cornerstones *[12]*

Existing Programs

In response to the growing need for the T-shaped engineer, several programs address the broader education represented by the horizontal bar of the "T". A summary of several of these programs follows:

- **Auburn University**. The Business-Engineering-Technology program (BET) [13] consists of a16-credit, four-semester minor including an internship and capstone design course. Students obtain a certificate in BET.
- **Clarkson University.** Offered is a BS in Engineering and Management [14]. Students graduate with a business degree by taking a combination of business and engineering core courses.
- **Lehigh University**. This four year cohort-based program results in a BS in Integrated Business and Engineering (IBE) degree [15]. This honors program provides a degree from the business college and consists of three years of engineering or business courses supplemented with a year of IBE cohort courses spread over the four years. The program requires a fifth year for students wishing to earn a BS in engineering or a BA in a business specialization. Some additional characteristics include:
  - Students acquire proficiency in a foreign language and encouraged to study abroad
  - Summer industrial internships are mandatory
  - Program culminates with a comprehensive senior capstone design project focused on entrepreneurship that incorporates marketing, strategic planning, and competitive analysis, along with product, process, and system design issues

- **Philadelphia University**. Established is the College of Design, Engineering, and Commerce (DEC)[16]. Students may matriculate in any of the three degree programs. Engineers receive a BS in engineering which is supplemented with four DEC interdisciplinary core courses plus a capstone course. The four DEC courses (Figure 4) include Design Processes, Business Models, Systems Analysis, and Research Methods.

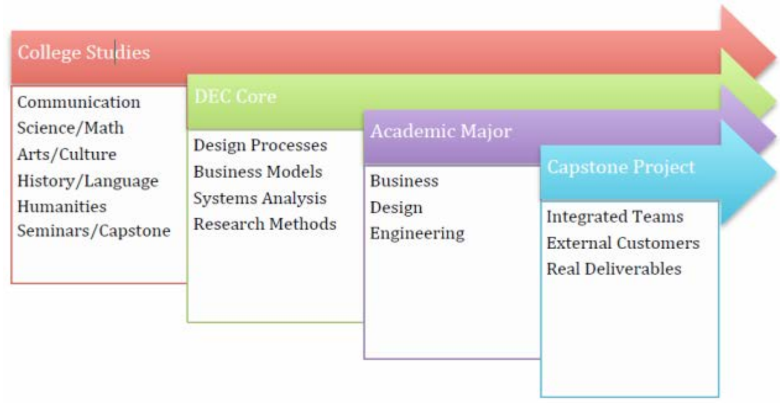

Figure 4 Philadelphia University College of DEC studies[16]

- **The Ohio State University.** The Integrated Business and Engineering (IBE) program is a four-year honors program consisting of a cohort of business and engineering students following their own course of study. In addition, they take enough credit hours in the complementary degree program to earn a minor and take 16 hours of IBE-specific courses as a cohort. Engineering students graduate with a BS degree, a minor in business, and an honors designation in IBE. Business students graduate with a BS degree, a minor in engineering sciences, and an honors designation in IBE.
- **University of Notre Dame.** Students in the Integrated Engineering and Business Practices Program [17] take a two-course sequence: "Integrated Engineering & Business Fundamentals" and "Advanced Integrated Engineering & Business Concepts."
- **University of Pennsylvania.** The Management and Technology Program [18] had its first graduates in 1978. Requiring a total of 46 courses, students pursue two full degrees concurrently: a Bachelor of Economics from the Wharton School and either a Bachelor of Science in Engineering or a Bachelor of Applied Science from Penn Engineering.
- **University of Texas El Paso**. A BS Engineering Leadership (E-Lead) [19] is a four-year engineering program that includes three leadership, two professional practice (paid internships), and two senior design courses.
- **Zhejiang University (Zhejiang Province, China).** Students are offered an Advanced Honor Class of Engineering Education [8]. Four modules are covered, including Engineering Foundation, Engineering Design, Engineering Management, and Engineering Practice. Students select two or three courses in each module.

History Leading to T-shaped engineering education at Ohio State

The Fundamentals of Engineering program, its genesis in the NSF-sponsored Gateway Engineering Education Coalition, was formed in large part to address poor engineering retention rates. In addition to improving retention, the program developed modern curricula, introduced technology into the classroom, developed faculty to be better teachers, and assisted students to become better and life-long learners. The Gateway schools agreed to adopt or adapt Drexel's E4 program for freshmen and sophomores placing engineering "up-front" and specifically included hands-on labs and incorporated design projects. Introducing design in the freshman year of engineering course work marked a change for a number of engineering programs and helped improve retention rates by involving and exciting students about engineering right from the beginning of their first term. The honors program (FEH) proposal was approved for Ohio State Honors students in 1997. The FEH Program is designed to further challenge the well-prepared, first-year engineering student by offering access to more advanced levels of study and by encouraging creative abilities and a sustained interest in advanced education and research.

Multidisciplinary capstone began in 2007 in the form of a one-year, company-sponsored project. The program focuses on applying the design process with teams comprised of four to six students from disciplines relevant to the sponsor-supplied open-ended problem. This process includes problem definition, primary and secondary research, creation of user needs and product requirements, conceptual design, system and detail design, mockups and prototyping, and user validation. Projects to develop new products and markets include business and industrial design students to complement the engineers. The course is taught by instructors with industry background and extends beyond the design process with special emphasis on professional skills development including project management; teamwork; technical and oral communication; business acumen; social, environmental, and global impacts; creativity; and ethics. Because many of these professional skills are missing as students enter their senior year, the course teaches many of these elements.

Social Innovation and Commercialization (SIAC) program is an extension of the multidisciplinary capstone by replacing the industrial clients with nonprofit organizations dealing with people with disabilities. Multidisciplinary teams usually include students skilled in the specific area of disability being addressed by the team (e.g. speech and language, physical therapy, occupational therapy, etc.). The team works with a selected nonprofit to identify unmet client needs that can be met with a new product. Working with end users or care givers (e.g. parents, therapists, and teachers working with children with autism), teams help identify an unmet need. Over the course of the capstone project, the team defines, designs, prototypes, and validates a product. A local social entrepreneur assists in the final commercialization of the product and remits revenue back to the original nonprofit partner. The primary additional elements of the T-shaped engineer include social awareness (of nonprofits and people with disabilities) and the issues associated with product commercialization.

Integrated Business and Engineering (IBE). To expand the promotion of educating the T-shaped engineer and introduce the various concepts at the earliest phase and spread them throughout the curriculum, Ohio State formed a new program called the Integrated Business and Engineering (IBE) program as described in more detail below.

The IBE Program

Based on the authors' research, interpretation of the "voice of the customer" (i.e. industry), and years of personal industrial and academic experience, the following interpretation of a T-shaped engineer is offered:

1. Sound technical expertise in one discipline
2. A solid business acumen including the issues associated with product commercialization
3. An entrepreneurial mindset supplemented with design thinking

4. Ability to function effectively on multifunctional teams
5. Courage to attack open-ended problems exhibiting life-long learning skills
6. Effective oral and written communication skills
7. Ability to perform critical thinking
8. Incorporates social, environment, and global issues

It is on this model that the college created the IBE program. The initial concept resulted from evaluating several programs. A review of the following programs: Michigan Tech's Enterprise Program [20], Purdue's EPICs program [21], and Lehigh University's IBE program [15] led to the development of the Integrated Business and Engineering Honors program.

Learning Objectives. As part of the approval process at Ohio State, the following learning outcomes were defined and approved by the university. The student learning objectives are listed as common, engineering, and business. While some suggest that engineering students are apt to gain more than business students from this program, it is clear that business students share significant common learning outcomes with engineering students and enjoy some specific to them.

Common:

- Experience theories and tools from a different discipline
- Develop critical thinking skills and entrepreneurial mindset
- Work in multidisciplinary teams
- Apply the tools of market analysis, competitive analysis and project valuation and the product development process
- Gain insight into business plan development and the societal, global, and environmental impact of product development

Engineering students:

- Understand the impact of technical decisions on business revenue and cost models
- Experience the value of creating value propositions and correctly interpreting user inputs in specifying and validating new products or services
- Understand how the allocation and organization of financial, human, and physical resources affects the product development process
- Develop a strategic approach to thinking based on economic constraints, competitive pressures, and organizational goals

Business students:

- Develop ability to apply an engineering mindset to business decisions
- Understand the impact of technical constraints and tradeoffs on business decisions
- Learn to match customer needs with technical and manufacturing feasibility
- Understand the fundamentals of and become conversant in range of engineering technologies

Performance Indicators. Yearly reporting is required by the university to ensure the success of the program. Success indicators (many of which will be known after the first cohort graduates) include:

- Student retention rate through the four years
- Internship placement rate of participants
- Job placement and starting salary of graduates
- Employer feedback on student performance
- Graduation rate with "Honors in Integrated Business and Engineering"

Curriculum Development. A variety of administrative hurdles, some real and some perceived, arose during the development of the concept. The first and foremost real hurdle is the amount of effort and time associated with creating a new degree program. This requires a series of approvals including faculty, curriculum and academic affairs committees, honors and scholars, university governance, and state governance. The typical approval time can exceed two years. Additionally, and related to this same topic, pushback came from several department chairs. They stated a concern that a new degree program would possibly attract all the best students from their (traditional) department. It was decided early in the process to reduce or eliminate both real and perceived hurdles by offering a program that allows students to remain in the department and receive a degree in their chosen major.

In a further attempt to streamline the approval process, it was decided to incorporate existing courses into the program rather than create a series of new courses as they did at Purdue EPICs program and Michigan Tech's Enterprise program. The cornerstones of the engineering program (Fundamental of Engineering for Honors and Multidisciplinary Capstone) were incorporated with modifications to benefit the integration of business and engineering students. Added to each of these courses are business elements that include the use of the "Business Model Canvas" [22]. The outline of the course structure for IBE for engineers is shown in Figure 5. A similar model exists for business students where engineering electives take the place of business electives for engineers.

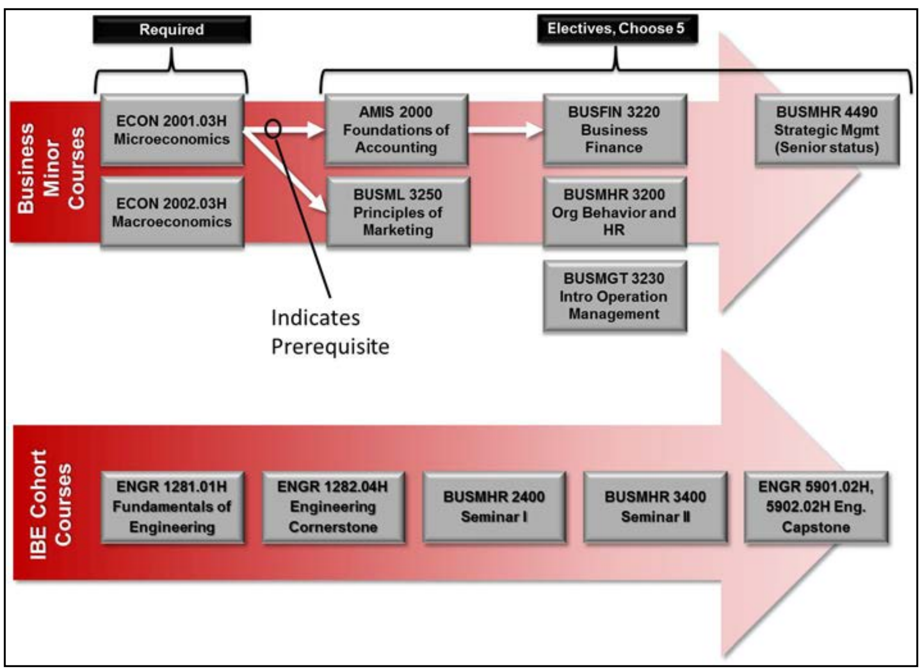

Figure 5 IBE engineering course sequence

The engineering curriculum consists of three primary parts (the business curriculum is similar):

- Engineering discipline
- Business minor courses
- IBE cohort courses

The IBE cohort courses include modified versions of the FEH Program's engineering courses, two business seminar courses, and a modified version of multidisciplinary capstone.

TABLE 1. IBE Student suggestions for extracurricular events

- Workshops with guest speakers (entrepreneurs, top engineers/execs)
- Company tours (understand different structures see manufacturing processes)
- Networking (learning how to professionally network)
- Professional development (leadership and communication skills, business etiquette including dining, working with international companies, interviewing, negotiating, etc.)
- Entrepreneurship/Startups (workshops with angel investors, serial entrepreneurs, venture capitalists, etc.)
- Business finances (workshop to understand investment planning)
- Elevator pitch coaching and competitions
- Provide real-world mini consulting opportunities
- Exercises to improve innovation and creativity
- Trip to a product design firm
- Personal development (team building, interviewing, resume writing, dress for success, business etiquette)
- Learn how to speak professionally and with good diction
- Social events to network with other IBE students

There exist no formal cohort courses in spring semester of sophomore and junior years. As a result of requested feedback from the first cohort, extracurricular professional development activities have been added to the spring semesters. A leadership group of IBE students is responsible for planning, coordinating, and executing various professional development activities during the spring semesters. A summary of the survey results showing student suggestions is included in Table 1.

The IBE First-Year Cornerstone. Of particular interest relative to achieving the learning outcomes expected of the T-shaped engineer are the details of the second semester freshman engineering course. This course consists of three parts:

- Designing a product
- Applying solid modeling, sketching, mockups, and personas
- Creating a business model

The design portion follows a traditional product development process taught in senior capstone and provides the student teams the opportunity to create interim graded deliverables as shown in Figure 6. A great deal of effort is spent defining a problem and the students follow the process in "Value Proposition Design" [23] to create a Value Map and Customer Profile. Once a primary task is defined, the students present a hypothesis and create a series of prioritized user "needs". The team uses these needs as a foundation on which to build design concepts. The R&D

Director of New Category Creation at Georgia Pacific (one of the industry IBE partners) provides a workshop teaching how to interview prospective users. The teams create an interrogation and listening guide. The concept design phase begins at the completion of Problem Definition and an industry expert provides an evening workshop on creativity and brainstorming. The students form teams and, in two hours, redesign, prototype, and validate a new backpack design. They query each other as users to define needs and again to validate their prototype. The R&D Director returns to class the next day to recreate the brainstorming energy—working now on the teams' product to be designed and prototyped during the semester.

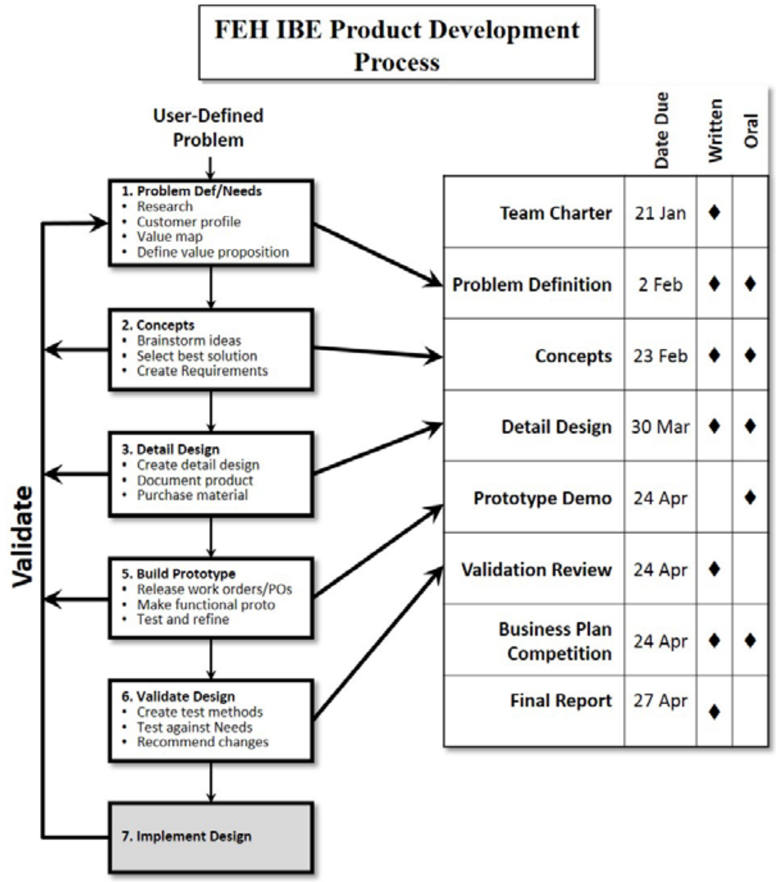

Figure 6 IBE course deliverables

This year, the teams' charter was to develop a product for backwoods campers—one that fills an unmet need. They learn that they must achieve "three "fits" [24] for their new product:

1. Paper fit—the product works
2. Market fit—people will buy it
3. Business fit—you can commercialize it for a profit

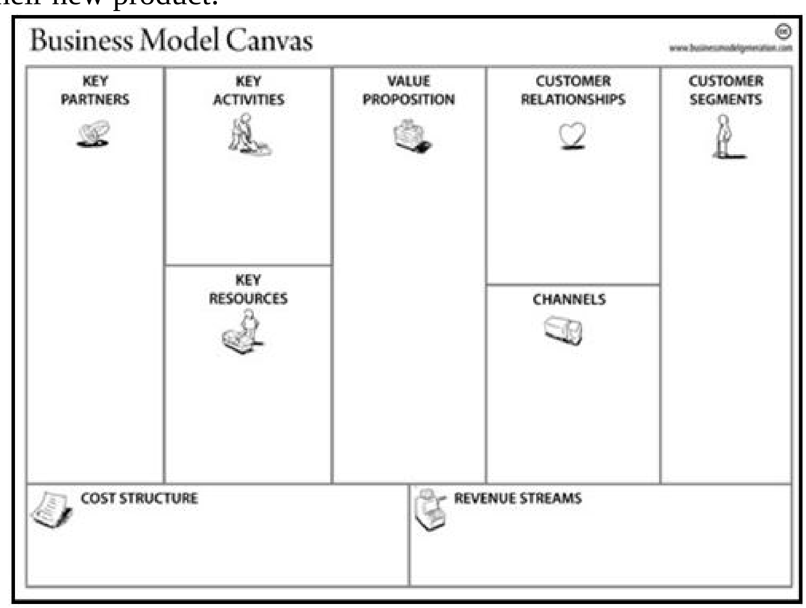

Figure 7 Business Model Canvas[22]

The students quickly learn that product development is an iterative process and are encouraged to continue querying their user base throughout the conceptual and detail design phase to ensure they are meeting a need and that people will be willing to buy their product. The teams continue to fit their product into the "Business Model Canvas" [22] (Figure 7) to ensure there exists a sound business model.

Beyond the value proposition, students evaluate the key activities, resources, and partners needed to start a company to build their product. As part of their initial research, they define an acceptable selling price and during the detail design phase they estimate manufacturing costs. While the level of effort is rudimentary with coaching from the teaching staff, the important learning objective is an understanding of the basic business model parameters.

The course culminates in a business plan competition where each team presents their product to a panel of industry judges. These folks represent sales, operations, general management, angel investors and venture capitalists, entrepreneurs, and corporate officers. A formal rubric is used to score presentations (Table 2). Scholarship prizes funded by industry go to the best technical presentation, best business presentation, and best overall presentation (only one prize to a team!).

IBE Senior Capstone. As with all engineering programs, the culminating IBE experience is the senior capstone design course. The first IBE capstone begins in 2016 and a modification to the current multidisciplinary course will create an "honors" version providing several differences. First, it has been explained by our career services personnel that many of the top (honors) students receive job offers before or during their fall semester of their senior year. Therefore, the value of using company-sponsored projects as a means to connect students and potential employers is less meaningful for students and employers alike. Secondly, the first-year IBE design course described above covers many of the same elements as the senior capstone and therefore encourages an increase in course challenge and scope. Discussions are underway with potential industry partners to help define a more meaningful and robust capstone experience.

Topic	Score
Opportunity (value proposition)	15
User Needs	10
Your Product	25
Going to Market	10
Financial Model	10
ROI Plan	5
Presentation	15
Discussion	10
TOTAL	**100**

Table 2 Business plan competition scoring

It is proposed that the IBE capstone course will begin at the end of the junior year by matching teams and clients and scoping a capstone product design project. It is intended that the client will hire two or more of the teammates for a summer internship and kick off the project assignment by having the entire team visit the company for two days at the beginning of the summer. During this visit, the team is introduced to the company, liaisons are established, and projects scopes are discussed. The interns will continue to work during the summer to research the project and to communicate on a bi-weekly basis with the remainder of the team. The deliverable at the end of the summer is a formal "problem definition" presentation with the entire team presenting to the client. This allows the team, or a portion of it, to fully immerse themselves in both primary and secondary research to fully understand the problem and succinctly identify user needs.

Finally, the project concludes with a formal business plan competition that is judged by senior industry representatives (representing marketing, manufacturing, engineering, finance, and entrepreneurship). Students focus on a commercialization plan including the three “fits” of product, market, and business viability.

Pedagogy. Regarding the learning process, IBE moves the students up Bloom’s (revised) taxonomy pyramid [25] (Figure 8) as early as their freshman year. As the teams move through the product development process, they participate (if only superficially in some cases) at every level. In many cases, first-year students have only experienced close-ended problem solving—problems with one known answer—and initially expect very specific directions regarding assignments. In this first-year IBE class, students are encouraged to take the information received, evaluate it, and apply it to their project. To help ensure success, the students are encouraged to concentrate less on ensuring they have the right answer and more on the design process and creative, independent analysis, and evaluation. They are told it is acceptable to make mistakes but not acceptable to not try.

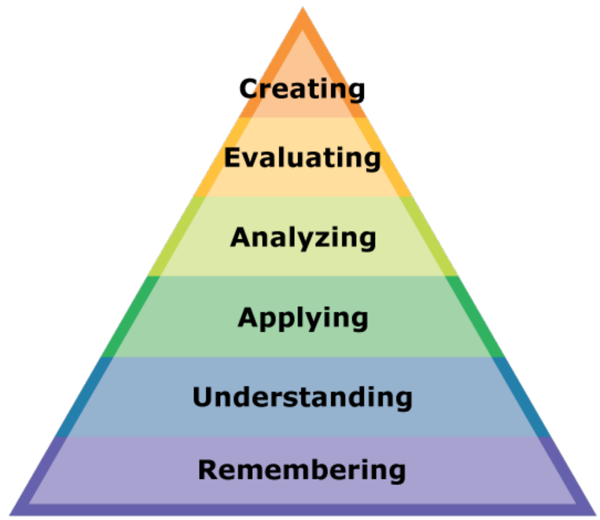

Figure 8 Bloom's (revised) taxonomy pyramid *[25]*

Recruiting

In order to attract the students with the best potential to succeed in the program, we invite all students accepted by the university as honors students in the colleges of business and engineering to apply formally to the program. We provide them with essay questions associated with their desire to be part of the program and to provide an example of a problem that can best be solved with a multidisciplinary team. In addition to making a qualitative judgment on the content of these essays, the number of potential Advanced Placement (AP) or International Baccalaureate (IB) courses that can offset college requirements play a part. It is clear that since IBE adds credit hours to an already stacked curriculum (especially for engineers), the students with a high level of accepted course credits will have the best opportunity for success. Invitations are sent just after students are accepted into the university honors program to provide an opportunity to attract students who might decide to go elsewhere.

Need for assessments

The effectiveness of creating new curriculum to meet the growing needs of industry and students must be continually evaluated and assessed to ensure we are achieving the expected learning outcomes. And, while much T-shaped learning results from team work, it is critical to evaluate individual performance. To be effective, assessment tools must be crafted for the context in which they are applied and must be easy to use, effectively assess outcomes, and exhibit value to both students and instructors. Relevant assessments must be developed, validated, and tested by educators before they will gain broad acceptance and be used to leverage curricular change needed to transform undergraduate engineering education. Currently, we collect continuous feedback from students in the form of peer reviews, weekly journal entries regarding a number of thoughtful topics about the program, and reflection pieces at the end of each course.

High quality assessment requires (1) clear learning targets, (2) clear purposes, (3) assessment methods that match the targets and purposes, (4) sampling for intended purposes, and (5) minimized bias and distortion [26]. The “assessment triangle” specifies that assessment evidence must align with the intended interpretation, and assessment measures must correspond to the conceptual model for development of the targeted knowledge or skills [27].

Development of authentic T-shaped parameters requires educational experiences that simulate those in the engineering profession—practices that differ from traditional lectures and problem sets with fixed answers. Team based, open-ended problems are one way to do this and many engineering capstone design courses provide this experience, so they can enable development of authentic knowledge, skills and abilities [28] [29][33]. Significant new learning requires learner reflection and feedback that is accurate, timely, and improvement-focused [30] [31] [27]).

Assessments for learning outcomes must satisfy the following requirements: (a) measure individual achievement within team environments; (b) provide measures authentic to engineering practice; (c) apply to diverse project, student, and course settings; and (d) find acceptance by the broad engineering education community and profession.

One of the prevalent course opportunities that often provide realistic project assignments is the multidisciplinary capstone course—especially those that create open-ended problems by sponsoring clients. Currently, many capstone assessments are based on team results leaving only peer assessments as a way to infer individual performance outcomes. The author has created a team that has begun research to develop authentic assessment tools to measure professional skill outcomes for senior capstone courses. It is planned that this work will form the foundation and methodology to expand to assess individual (rather than team) outcomes for the T-shaped engineer.

Lessons learned

Creating change within a university is always an invitation to negotiate hurdles and potholes. By the very nature of most research-focused universities, tenure and associated research pressure often distract attention from creating change in undergraduate education. The four pillars of learning often become the many silos of disciplines. Having an engineering education function within the college of engineering assists greatly in the ability to create opportunities like IBE. Creating collaborations with business, design, and other liberal arts colleges is necessary to create the true broad education sought for the T-shaped engineer.

Industry has shown a great deal of interest in the IBE program and several partners have already committed time and funding to help establish the program, participate in instruction, provide professional resources for extra-curricular learning, hire interns, and support senior capstone projects. In the words of one of our early partners, “Georgia-Pacific believes strongly in hiring recent graduates from programs such as Ohio State’s IBE program for three reasons: 1) students work interdisciplinary which more closely simulates corporate environments; 2) students solve problems holistically rather than focusing solely on technology; and 3) students solve problems responding to real consumer frustrations and challenges. This kind of experience helps students become better prepared as they enter corporate environments.”

The challenge is to fit corporate instructional pieces into the normal flow of course content rather than create “recruiting” opportunities. In return for participation, the program provides industry recruiters interaction with the students beginning in their freshman year. Talent managers are learning to identify bright students early in their academic career, offer them internships to provide an interviewing mechanism, and offer them jobs well before the senior career fairs.

A growing population of students has an interest in experiential learning, working with teams, and addressing real-world problems. Those students expressing entrepreneurial thinking traits are some of the ones particularly interested in our program. Creating products and associated markets and creating business opportunities to make successful ventures meet the three required fits (a product that works, a market that will buy it, and a business model that will produce a profit while addressing social, environmental, and global issues).

Next Steps

The next effort is attracting more corporate partners—those companies interested in access to some of the brightest and broadly educated students in their freshman year. It is these partners who will help shape the program, hire interns in the early years, make contributions in the classroom, participate in extra-curricular activities, provide open-ended capstone projects, and hire IBE students—the engineers representing the future.

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