



Intrapreneurship: A Collaborative Learning Approach between Industry and Academics to Build Critical Skills

Dr. Ross A. Lee, Villanova University

ROSS LEE

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Ross Lee is a professor and Engineering Fellow at Villanova University where he teaches Engineering Entrepreneurship, Sustainable Industrial Chemistry, Sustainable Materials and Design, Green Science, and Biomimicry. Dr. Lee has over 36 years of industrial experience with the DuPont company (retired July 2009) spanning a wide variety of technology, product and new business developments including films, resins and innovative packaging systems.

He has authored or coauthored over 20 patents and publications. In his most recent position, Ross was responsible for bringing new technology to packaging through open innovation and was instrumental in developing DuPont's alliances with Plantec and Scanbuy. He has a Ph.D. in Organic Chemistry from Michigan State University and a B.S. in Chemistry from the University of Rochester. Ross and his family reside in Chesapeake City, Maryland

Dr. Leo E. Hanifin, University of Detroit Mercy

After engineering positions in the computer, aerospace and automotive industries, Dr. Hanifin led a research center focused on manufacturing technology at Rensselaer Polytechnic Institute for eleven years. He then served as Dean of the College of Engineering and Science at the University of Detroit Mercy for twenty-one years. He is now retired from full-time academic responsibilities, but continues to consult in higher education, study innovation methods and advocate for effective transit systems.

Intrapreneurship and T-Shaped Engineers: a collaborative learning approach between industry and academics to build T-shaped and other critical skills.

Dr. Ross A. Lee (Villanova University) and Dr. Leo E. Hanifin (University of Detroit Mercy)

Abstract

Most of the students engaging in entrepreneurship at engineering schools will not start their own businesses as their first employment. Most will enter industry. The challenge to use their entrepreneurial interests and skills then resides in their abilities to innovate, engage, communicate and lead in an industrial environment to identify and pursue new opportunities and directions for these organizations.

Building on an extensive study¹ conducted with a team comprised of faculty from four leading colleges, and encompassing an industrial advisory group composed of leaders from ten companies spanning large material based corporations to large consumer products goods companies to recognized world class innovation companies, this paper will describe the collaborative process used to identify the areas noted as most critical for intrapreneurship, and the recommended next steps to develop skills in these areas through engineering education. The T-shaped engineer and T-shaped skills, that address several of the key areas, will be used to illustrate both curricula-based and non-curricula-based educational opportunities. This will include a new collaborative internship with specific metrics to ensure that the industrial experience embraces, tests for, and collaboratively measures the progress in the development of the intrapreneurial skill.

Introduction

An intrapreneurship study¹ began in the fall of 2011, thanks to a grant from the Kern Family Foundation to four schools in KEEN (Kern Engineering Entrepreneurship Network). KEEN was formed to develop an entrepreneurial mindset in today's engineers. Founder Robert Kern (successful entrepreneur of Generac[®] fame) had a vision to differentiate American engineers by bringing an entrepreneurial mindset to undergraduate engineering education. Since most of today's graduating engineers do not start their own businesses but join established corporations or institutions, a key focus of this four school grant was to understand intrapreneurship, which is the term used to describe successful entrepreneurial efforts in an existing corporation or institution. This usage is consistent with the general usage of the word, if one searches the internet, as well as in published articles, such as the one cited here². Innovation is an area that is associated with intrapreneurship, and as we were discussing intrapreneurship during our corporate visits, we also obtained information on innovation, and included those insights in our previous paper¹. The purpose of the intrapreneurship study¹ was to first understand the key competency areas for successful intrapreneurship in corporations and institutions through a

collaborative intercollegiate and cross industry effort, and then to translate these into educational opportunities to develop the associated skills in today's engineers. The study¹ was conducted in three phases that involved:

1. Understanding intrapreneurship today through corporate visits and sharing information on successful practices and examples
2. Determining the most important competency areas associated with these practices and examples
3. Determining engineering educational opportunities to develop the appropriate skills for these competency areas

Starting with the collaborative process used to engage the academic and industry participants, followed by the key competency areas identified, this paper will focus on the ways in which these competencies have, and can be developed through engineering education and educational opportunities. The area of T-shaped education, that touches several of the key competency areas, will be used as an example.

Collaborative Process

Figure 1 illustrates the four schools that came together as a “dense network”³. The process to choose these schools was the result of an exercise at the 2011 annual winter meeting of KEEN that challenged the group to seek dense networks of schools with synergistic opportunities. Baylor, University of Dayton, University of Detroit Mercy and Villanova recognized that each engaged with industry in varying and complementary ways. The University of Dayton had an extensive industry sponsored project system tapping local industry in the Ohio area; the University of Detroit Mercy had extensive co-op and industry-sponsored educational relationships with the automobile and aerospace industry; Baylor had an extensive intrapreneurship training effort underway with corporations globally, as well as industry-sponsored projects in the Dallas area, and Villanova engaged professors with local industrial backgrounds in their engineering entrepreneurship minor providing a rich network of industrial opportunities in the Philadelphia area. **Thus, the critical element in the academic collaboration was selecting collaboration partners that could provide industrial synergy from a regional, as well as an industrial focus, perspective.**

Figure 1: The Helping Hands Dense Network (HHDN)



Figure 2 illustrates the ten corporations that were selected to form the Industry Team for providing their perspectives on innovation and intrapreneurship through corporate visits and first hand sharing from engineers.



Figure 2: Corporations represented on the Industry Team that were visited in the intrapreneurship study

The process used to establish this group was described in a previous publication¹. It involved each school selecting the local industries they had strong relationships with, and that would provide leading edge information regarding intrapreneurship across a breadth of industry types. This resulted in the ten corporations shown in Figure 2. High level company representatives with a perspective on how intrapreneurship occurred in their organization, and who could assemble the right people to engage with us (the “Intrapreneurship Study Team”) during our

visits were then identified at each corporation. To gain their enthusiastic participation it was important to clearly convey what the corporation would get from the engagement, and to ensure that the time together was well spent, and effective (3 hour maximum sessions were promised that were only exceeded by the enthusiastic hosts). Each representative on the Intrapreneurship Study Team was assigned sponsorship for the companies they suggested. The sponsors identified and contacted the appropriate level representative, and worked out the plan and logistics for the Intrapreneurship Study Team visit. Alumni and development groups at the colleges were engaged and kept informed as appropriate. Once all the individual company representatives were identified, a formal charter was developed for this group that was named the Industry Team (called IT). The Intrapreneurship Study Team leader, Leo Hanifin, made personal contacts to each for a kick off meeting to lay out the reason for the study, and the engagement of each corporation in the Intrapreneurship Study Team visits. **The critical elements of the collaborative process to engage industry were thus:**

- 1. Choosing a cross section of industry in breadth of intrapreneurial opportunities.**
- 2. Leveraging the local, synergistic relationships of the dense academic network including personal responsibility, and accountability of individual representatives for engaging the right individuals and handling logistics.**
- 3. Establishing a clear charter and achieving buy in from the Industry Team in a kick off meeting led by the leader of the Intrapreneurship Study Team.**
- 4. Ensuring that the engaged corporations and their leaders saw value for the time spent in the engagements, and reaped the goal rewards of understanding what others were doing in this area, as well as having an opportunity to shape the education of future engineers, in ways that they valued.**

Key Competency and Focus Areas for Education

Figure 3 is a bar graph of the key competency areas identified from the company visits. The process to establish these has been previously described¹, and involved asking the over 100 corporate leaders involved, “what behaviors and competencies do you want in your new engineers that would make them more effective innovators and intrapreneurs in your company?” The responses essentially said¹:

“We want engineers who are confident, competent, open minded engineers who work effectively on teams that employ experimentation, analysis and innovation to create and “sell” products that are truly responsive to customers around the globe”

Actually, no one leader said precisely that. This is what you get if you “boil down” 168 recommendations during intensive visits (Intrapreneurship Study Team visits) to an Air Force innovation center and nine major corporations from a wide variety of industries (automotive, aerospace, building, chemical/materials, communication, food, information and medical). The specific responses and dialog reveal a rich array of attributes that include not only competencies,

but personal behaviors, values and characteristics that are deemed by innovation leaders to be necessary to becoming an intrapreneur as we have defined intrapreneurship above.

The Intrapreneurship Study Team then grouped these responses into these nine competency areas that are shown in Figure 3. :

1. Technical competence
2. Innovation
3. Anthropologist
4. Cross-pollinator
5. Experimenter
6. Communication/value proposition
7. Teamwork
8. Breadth (“T-shaped”)
9. Confidence

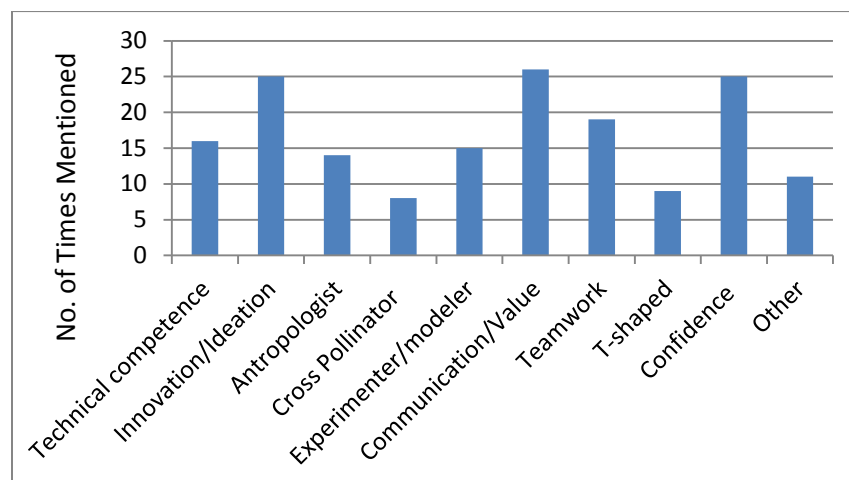


Figure 3: Key Competency Areas for Intrapreneurship and Innovation Plotted vs. Number of Times Mentioned by Corporate Leaders

1. Technical competence relates to having enough depth to create innovative solutions but, importantly, not to the extent that blindsides other perspectives.
2. Innovation/ideation relates to the ability to come up with innovative ideas, patents and designs and to be inquisitive and curious.

Anthropologist, cross pollinator and experimenter, are really subsets of innovation, and are from Tom Kelley’s book, “The Ten Faces of Innovation”⁴

3. Anthropologist refers to competencies similar to those expected in an anthropologist, and relate to the ability to understand and connect with the world, with specific mention of

the ability to understand customer needs through empathetic observation, and the ability to connect one's actions with positive benefits to the rest of the world.

4. Cross-pollinator refers to the ability to bring ideas and solutions from area to another. It relates to the associative skills mentioned in the book, "The Innovator's DNA" by Dyer et.al.⁵.
5. Experimenter relates to hands on abilities in doing experiments and having a real, hands on feel for the area, as well as to knowing how to quickly test a concept or design via jerry rigging a prototype, or doing virtual modeling.
6. Communication/Value Proposition refers to the ability to effectively communicate across multiple disciplines and to be able to understand the value of a technology-based solution and communicate (and in some cases "sell") it in an understandable and compelling way to cross disciplines including customers and clients.
7. Teamwork refers to the ability to work effectively with all types of people, and to be able to lead, as well as, follow.
8. T-shaped was explicitly mentioned, and will be discussed separately as its own educational focus area.
9. Confidence refers to the ability to question the status quo and challenge conventional wisdom in a way that conveys knowledge, conviction and passion, while embracing the associated risk (including failure) in order to make a difference. The specific inputs that relate to confidence from each of the companies visited are described in detail in our earlier publication.¹ Confidence has also been identified as its own educational focus area, and is the subject of a recently accepted publication.⁶

These were then translated into five educational opportunity areas for engineering education (Fig. 4). Each block, except for the center one, represent educational opportunity areas that taken together would help to build most, if not all, of the competency areas mentioned in the corporate visits and shown in Figure 3. T-shaped education, Communication and Value proposition, and Confidence explicitly address all nine competency areas except for area 2 (Innovation/Ideation) and area 5 (Experimenter). Intellectual Property, from the standpoint of a learning opportunity to assess and quickly build upon prior art via testing and researching new concepts, and Empathetic Learning, from the standpoint of a learning opportunity to observe potential customer behavior for new opportunities, both address areas 2 and 5, and build upon the previously reported learning's from the corporate visits¹. The central block in Figure 4 represents the integration. The Intrapreneurship Study Team felt that understanding the educational opportunities for each, and then integrating them to whatever extent possible, would provide the greatest opportunity to build intrapreneurial competence in today's engineers. These were therefore selected, by the Intrapreneurship Study Team, as the areas that would make the most sense to focus on. Each educational focus area was then researched to determine what had already been done to develop competence in that area through education. Two areas have been completed and are being published now. One is the area marked "Confidence" in Figure 4 that has already been

mentioned⁶. The other is in the area marked “T-shaped Education” in Figure 4. This will be the focus of the remainder of this paper, and will be used as an example to convey the final of step of the intrapreneurship study process, which is to build intrapreneurship competency through engineering educational opportunities. Potential challenges and obstacles to achieve this are identifying what new and differentiated educational opportunities should be provided, how best to integrate these into the engineering education experience without adversely affecting other parts of the curriculum, and how to assess their effectiveness in developing the competencies needed for intrapreneurship. The ultimate measure of how effective this approach is will be in the feedback from industry on engineers who have been exposed to these opportunities in their engineering education. Metrics could include specific intrapreneurial accomplishments and their impact, such as those relayed to us in our corporate visits, as well as more quantitative measures of success such as salary increases and promotional opportunities. There is also a need to link these practical assessments with learning outcome assessments in the educational process. At the recent, “T-Summit 2015”, focused on the importance of, and the educational processes to build T-shaped competence, held at Michigan State University on March 16-17, 2015, several authors discussed the assessment of desired learning outcomes leading to this competency. In one excellent example entitled, “Defining, Measuring, Advancing ‘T’ Competencies: How Are We Doing? How Could We Do Better?”, author Debra Humphreys⁷ mentions the Association of American Colleges and University’s (AACU’s) “VALUE Rubrics” that have been developed for 15 learning outcomes almost all of which are connected to T-shaped competence and through our findings, intrapreneurship. These include teamwork, oral and written communication, intercultural knowledge and engagement, problem-solving, and integrative and applied learning (that directly relates to the cross-pollination competency mentioned earlier). The use of rubrics like these may provide a way to assess proficiency in the focused educational opportunity areas designed to build the desired intrapreneurship competencies.

Integrated Education Areas to Build Intrapreneurship (IShip) Competencies

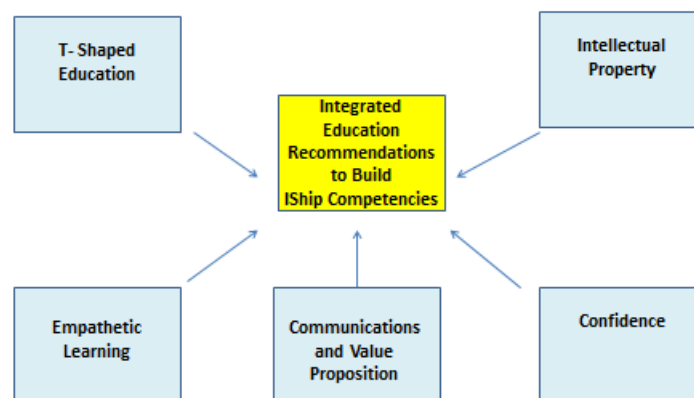


Figure 4: The Key Educational Focus Areas from the Intrapreneurship Study

The T-shaped Engineer

“T-Shaped People” is a term coined over 20 years ago by David Guest as it applied to a rounded person equally comfortable with information systems and modern management techniques⁸. Jim Spohrer, at IBM, and David Gardner at Michigan State University, have recently emphasized the critical need for T-shaped professionals to face the challenges of the future, and have emphasized, as our intrapreneurship study has, the critical need to develop these skills in our educational processes⁹. These authors used the image shown in Fig. 5 that emphasizes a stem comprised of depth in at least one discipline and system, and a crossbar of breadth including the competencies needed to understand, engage, communicate, contribute to, and lead innovation in today’s multidiscipline, global systems.

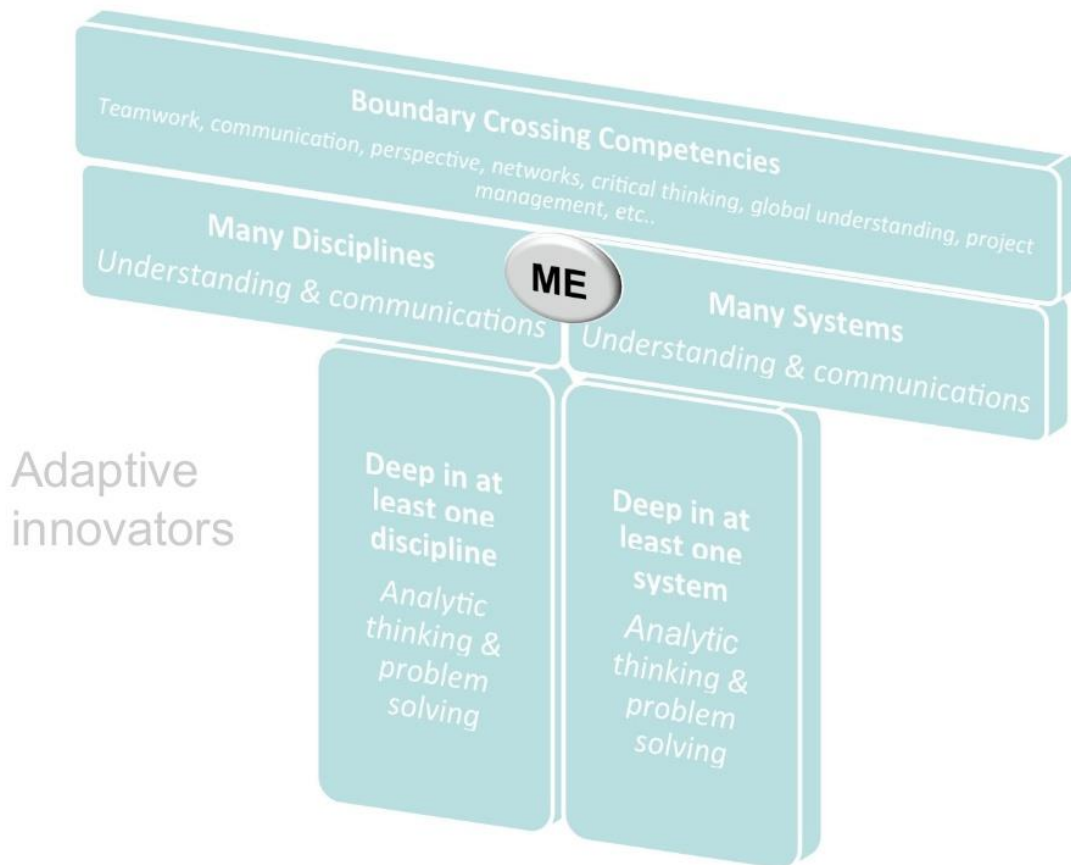


Figure 5: T- Shaped Icon by Jim Spohrer and Phil Gardner⁹

Others¹⁰ have engaged similar “T” icons to convey depth (stem) and breadth (crossbar). Unfortunately this icon can also be viewed as connoting an orthogonal, vs. an integrated relationship, since it could appear to some that the discipline depth of the stem is butting against, rather than integrating with, the cross discipline breadth. To remedy this, we have developed a new icon (Figure 6) that was inspired by Maxwell’s experiment in 1861 to produce white light from its red, blue and green additive components¹¹. We believe this more effectively conveys the integrative aspect of the T-shaped individual, as that of someone who develops a “full spectrum” vision, by integrating their own deep stem discipline and perspective, with their cross-bar competencies, to understand and engage multiple disciplines, multiple cultures, team, and system perspectives. Without this integration, the ability to see and effectively act on opportunities is challenged by being left “color blind” in critical areas. In this way, it is easy to see how the T- shaped engineer addresses the multiple, highlighted, key recommended competency areas from Figure 3, reproduced in Figure 7, of Technical competence, Anthropologist, Cross Pollinator, Communication/Value, and Teamwork.

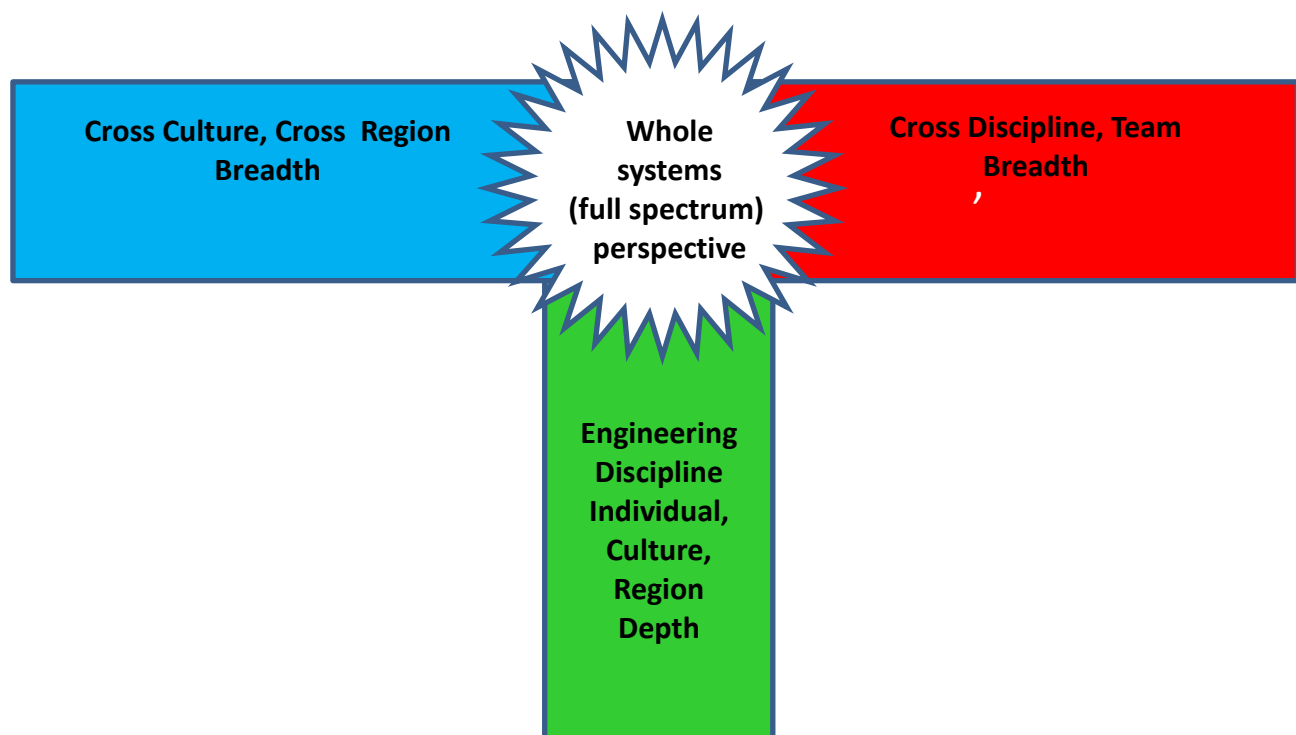


Figure 6: A T-shaped Icon to Emphasize Integration vs. Buttreassing of the Depth and Breadth

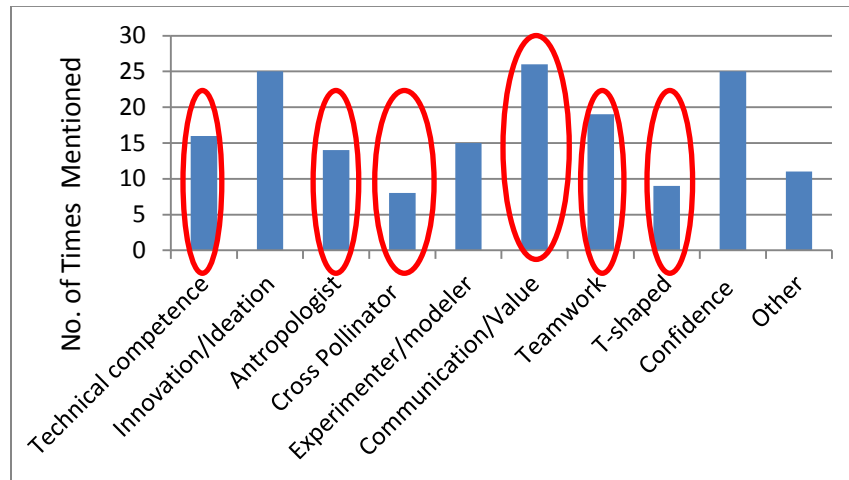


Figure 7: Key Competency Areas Related to T-Shaped Skills

What has been done so far to build T-shaped skills in engineering education?

Determining what needs to be done to build the competencies in each of the educational focus areas starts with understanding what has already been done in that area in engineering education. In the example of T-shaped education and skills, the following stand out:

- As described on their Engineering Diversity Program webpage, Stanford University has embedded the concept of T-shaped skills in their overall engineering vision¹². Stanford's E140a – "Leadership of Ventures" course, that is offered in their entrepreneurship program¹³ explicitly mentions developing T-shaped skills. From the description provided, the course includes cross-discipline instructors, external projects, and inter-discipline team work. These, in and of themselves, represent ways to build top of the T breadth in engineers.
- Joe Tranquillo, of Bucknell University (also a KEEN school), recently published¹⁴ an excellent paper describing specific examples to promote T-shaped skills. These involved cross discipline classes with cross discipline projects and instructors. A particularly

striking example is a learning experience in a traditional signals and systems biomedical engineering class that required a cross discipline twist: producing a musical instrument from biological signals. The cross discipline induced constraints forced students to engage and dramatically learn from cross discipline subject matter experts. Other elements include the ability to learn from reflection, and being evaluated according to the metrics of the cross discipline vs. one's own discipline. Cited references provide similar examples of cross-discipline skill building through cross-discipline courses and instruction.

- Xiaodong Zou et.al. of Zhejiang University, describe approaches that China is taking to effect the right balance in T-shaped skills in engineering education¹⁵. The areas of focus include reducing the breadth of engineering disciplines to narrow and deepen the stem of the T, as well as more strongly developing the cross-discipline skills in the top of the T by establishing required cross-discipline electives. This paper also emphasizes the value in cross-discipline projects.
- There are programs in place at many institutions that can promote T-shaped skills. Of the four schools in the intrapreneurship study:
 - Baylor University and the University of Dayton provide opportunities for cross discipline, external industry sponsored projects
 - The University of Detroit Mercy involves the students from architecture, business, digital media, nursing and psychology in their engineering design projects
 - Villanova sponsors and encourages engineering participation in social outreach projects; the Villanova School of Business, the College of Engineering and other schools across campus engage in numerous cross college and cross discipline entrepreneurial contests that involve multidiscipline teams and multidiscipline judging and assessment. Again, thanks to a KEEN grant, Villanova has established a very popular, engineering entrepreneurship minor that develops T-shaped skills via cross-discipline instruction and curriculum, a rich inclusion of external, cross-discipline guest lecturers, and course requirements to work in multidiscipline teams and present to multidiscipline judges in capstone "Trade Show", and final business proposition pitching events.
 - All four schools involve liberal arts requirements in the engineering curriculum that build top of the T breadth for T-shaped education.

What is recommended to build the T-shaped competency in today's engineering education?

Providing concrete recommendations to build the key competency areas identified in the collaborative industry/academic process represents the last step and final outcome of the intrapreneurship study. For the T-shaped education example, the following are recommended based on what has already been done, and what can further be done to develop this competency in today's engineering education.

- **Preserve the right depth of the stem of the T.** Preserve what is already in place for the core discipline and ensure that this is not compromised as programs are developed to expand breadth via the top of the T. This builds on what China is doing to ensure the stem of the T is appropriate and deep. As we heard in the company visits, some of the engineering core skills that were highly valued rely on state of the art advances such as those taking place in virtual modeling and 3D prototyping for concept evaluation. At Villanova, as at all ABET certified engineering schools, the core engineering courses are reviewed via industry represented Advisory Boards, to ensure they are relevant and effective. This provides a continuing way to ensure this.
- **Assist in selecting course electives to help build the top of the T breadth.** As mentioned, the four colleges that were part of this study are liberal arts based and do require cross discipline electives in the engineering curriculum. Though required as a distribution requirement, there is an opportunity to advise students on courses to help develop their “top of the T”. In this way, we would not be seeking to add additional cross-discipline courses to an already tight engineering curriculum, but would be ensuring the best choices for cross discipline courses to develop the T.
- **Provide explicit cross disciplinary experiences.** At Villanova, in the Spring of 2014, we co-listed a course on Biomimicry in the College of Engineering and in the College of Arts and Sciences. This resulted in a class comprised of almost exactly equal numbers (13-14 each) of engineering and arts and sciences students. This made for very rich cross discipline discussion in group projects that helped to foster cross-discipline communication and critical thinking skills. The cross discipline group critical thinking exercises that were performed each week in the second half of the 2 hour 45 minute class period received top ratings in the end of semester class survey for effectiveness, and were among the most mentioned elements of the course for “learned the most from”.

- **Provide a collaborative, T-shape focused, internship.** Building on the collaborative effort of the intrapreneurship study, Villanova and Campbell's (one of the intrapreneurship study Industry Team members) are modelling a new T-shape guided intrapreneurial internship. The job description was jointly written by Villanova and Campbell's to provide the following T-shaped (and intrapreneurial) outcomes:
 - a. Applies engineering expertise to situation analysis and solution development.
 - b. Develops and applies insights from data collection to business opportunities
 - c. Organizes and presents information in a clear, effective and professional manner
 - d. Understands the science and engineering basis for the problem
 - e. Demonstrates data based problem analysis and problem solution skills
 - f. Engages with and communicates in cross-functional teams
 - g. Understands consumer value and business opportunity associated with technology solutions

As can be seen, these outcomes include engineering discipline skills associated with the stem of the T (for outcomes such as a,d, and e), as well as cross-discipline skills associated with the cross bar of the T (for outcomes such as b,c, f and g). These outcomes also relate to the intrapreneurial competency areas of Figure 3, as described above for the correlation of T-shaped skills to these competency areas that include technical, innovation, anthropology, cross pollination, communication of the value, and teamwork. The outcomes also relate to the "Engineer of 2020"¹⁶ as it calls for the ability for engineers to be able to engage and communicate across multidiscipline and rapidly changing conditions.

The first internship is underway in the Spring of 2015 and will be assessed at the end of the Spring semester.

Conclusions.

We have described a collaborative process between multiple colleges and multiple corporations and one government institution that effectively identified the key competency areas that industry recognizes as most valuable for intrapreneurship within their corporations and institutions. Using T-shaped education as an example of one of the key competency areas identified in the intrapreneurship study, we have demonstrated how the area can be researched to understand what is being done today to build this competency, and provided recommendations for what to change and what not to change in today's engineering education to further develop this competency. This particular T-shaped education example is rapidly becoming recognized as a critical need, not only at the college level, but through the entire educational process, as the recent work by Jim Spohrer and Phil Gardner emphasize⁹. We have developed a new T-shaped icon to emphasize the integration of broad cross-discipline skills with the deep, specialty discipline skills to enable a full spectrum or whole system vision and perspective. We have only touched on

assessment and mentioned that the ultimate test will be in industry, but that rubrics, such as AACU's VALUE Rubrics, may help measure proficiency as these competencies are being developed in the educational opportunities mentioned. Finally, the T-shaped competency in particular, is not only so needed, as identified through this work, for intrapreneurship, but is equally so important for developing whole system solutions to the complex problems of the future. At Villanova we are also using the T-shaped education model to develop whole system (social, technical, environmental, economic and political) analytical and problem solving competence to deliver robust and resilient sustainable engineering solutions in both Master's, and soon to be added, PhD programs in Sustainable Engineering. The PhD program will use T-shaped education to provide a differentiated, whole systems approach to complex sustainability solutions, linking core discipline and sustainable engineering research. Recommendations for engineering educational changes to develop other competency areas, such as confidence⁶, will be subjects of forthcoming publications. Integrating these efforts will help to provide future engineers with the key competencies they will need to demonstrate intrapreneurship in existing corporations and institutions faced with the complex problems of the future.

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