open
MARCH 25-27, 2010
SAN FRANCISCO

PEER-REVIEWED PAPER

Instilling the Entrepreneurial Engineering Mindset in College Undergraduates: A Panel Presentation

Timothy J. Kriewall, KEEN Program Director, Kern Family Foundation

Abstract

Many universities offer entrepreneurship education. The Kern Entrepreneurship Education Network (KEEN) offers a different form of entrepreneurial education for engineering students. In contrast to entrepreneurship education, KEEN schools are charged with changing engineering education by instilling the entrepreneurial mindset into *all* of their engineering students so that as graduates these engineers will be entrepreneurial whether they are engineers drawing a salary, intrapreneurs in mid- to large-sized companies, or principals in start-up companies. This paper will describe the four defining characteristics of entrepreneurial engineers and the theory of change being followed by this network of colleges. An assessment rubric will be described from which a SWOT analysis of 11 attributes can be formulated.

Introduction

This paper represents an overview of the NCIIA panel session at which it will be presented. In essence, it is a white paper explaining a philanthropic effort to change engineering education in selected, independent colleges by instilling an entrepreneurial mindset into the pedagogy of the engineering colleges participating in this initiative. The viewpoints expressed herein are based on the life experiences of the founders of the Kern Family Foundation (Pistrui and Blessing and Mekemson 2008) as well as the author's. The viewpoints are not unlike those expressed in recent literature (Goldberg 2006), and they are espoused by member institutions (Table 1). The approach and examples are not meant to be put forth as superior to other approaches, but rather as a paradigm that has engendered broad appeal to twenty ABET-accredited, independent colleges. Assessment data are being collected for the purpose of validating the approach as graduates matriculate through the schools.

Entrepreneurship has been simply defined as self-employment through business ownership that has significant elements of risk, control, and reward. (This definition of entrepreneurship was coined by John Hughes, the Coleman Foundation's Chairman Emeritus.). Many other definitions have been penned, but Hughes' definition is one of the most succinct. In recent times, more and more attention is being given to the need for entrepreneurial businesses that will create new products and employment opportunities for American workers. Many universities are placing increasing emphasis on entrepreneurship course offerings, certificates of achievement, academic minors, and graduate degrees in entrepreneurship. Many Americans look to entrepreneurs as the source for new business and new jobs to strengthen the country's

economy.

Bradley University (Peoria, IL)
Case Western Reserve University (Cleveland, OH)
University of Detroit-Mercy (Detroit, MI)*
Illinois Institute of Technology (Chicago, IL)*
Kettering University (Flint, MI)*
Lawrence Technological University (Southfield, MI)*
Milwaukee School of Engineering (Milwaukee, WI)
Ohio Northern University (Ada, OH)
Calvin College (Grand Rapids, MI)
University of Evansville (Evansville, IN)
Mercer University (Macon, GA)
Villanova University (Villanova, PA)
Baylor University (Waco, TX)
Boston University (Boston, MA)
University of Dayton (Dayton, OH)*
Gonzaga University (Spokane, WA)
Norwich University (Northfield, VT)
Saint Louis University (St. Louis, MO)
Santa Clara University (Santa Clara, CA)
Worcester Polytechnic Institute (Worcester, MA)
*Those KEEN colleges presenting at the 2010 NCIIA meeting in support of this paper.

Table 1. Kern Entrepreneurship Education Network Colleges and Universities

A complementary approach to entrepreneurship education is to prepare entrepreneurially minded engineers. This approach is being supported, in part, by the Kern Family Foundation of Waukesha, WI. Through its Kern Entrepreneurship Education Network (KEEN), a specifically selected network of independent colleges and universities (Table 1) are working cooperatively to create a modified engineering graduate compared to 20th century engineering graduates. The objective is to instill an entrepreneurial mindset in all the engineers that matriculate through these engineering colleges by modifying the schools' engineering pedagogy. Without affecting the fundamental technical skills these undergraduates are taught, the KEEN initiative is intended to teach, in addition, four entrepreneurial engineering characteristics: engineering knowledge required to commercialize an innovative concept to make it market-worthy; customer awareness; business acumen; and personal character to maintain our societal values.

The approach is to instill these characteristics in engineers' undergraduate education, so that graduates will be better prepared to enter an entrepreneurial workforce to the technical advantage of the business in which they work. The advantage engineers in general have to non-technically educated business professionals is that they understand complex technologies that may be leveraged for customer benefit. They are able to translate technologies to meet unspoken and unmet needs in the marketplace. In their book *Competing for the Future*, Hamel and Prahalad (1994) opine that business leaders take their customers to where they want to be but they don't know it yet. Furthermore, customers cannot define future product needs; they can only describe what may be improved in existing products. The future, therefore, is defined

by those prescient enough to see technology's future applications.

In contrast to the traditional analytical engineer, who is well-equipped to solve problems, an entrepreneurial engineer will be prescient in his or her view of the world. An entrepreneurially minded engineer will place product benefits before design features, and will be able to uniquely leverage technology to fill unmet customer needs. The purpose of entrepreneurial engineering is to design value-added products and processes that create demand for new innovations. The result is positive cash flow that creates revenue and regenerative profits for the enterprise that produces the product. As Peters and Waterman expressed in their seminal work *In Search of Excellence* (1982), any company that exists to make money is destined for failure. Instead, companies who place meeting and exceeding their customers' requirements will have profits as a natural consequence. Entrepreneurially minded engineers will place creating value ahead of personal wealth generation. Yet, if they do their work well, profits will be a natural consequence, a metric of their passion to fill unmet market needs.

Attributes characteristic of an entrepreneurial 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 their ideas fit into the larger context of society, and proficiency in communicating his or her ideas. Why these attributes? Table 2 elaborates.

Entrepreneurially minded engineers can be:

- staff engineers working for companies in a traditional engineering role, or
- intrapreneurial engineers who take leadership roles within companies to create, define, design, and produce incremental improvements to products to retain and/or capture market share in order to stay ahead of competitive products or meet the needs of changing markets, or
- entrepreneurial engineers who are financial stakeholders in the firms which they direct.

Entrepreneurial companies need employees who are both the generators of new ideas and the supporters of new ideas. Engineers working in technology-based companies, even in traditional engineering roles, will need to support change necessary for business growth. This is an attribute of an entrepreneurially minded engineer.

What Does the Entrepreneurial Engineer Need to Learn?

The distinguishing attributes of the entrepreneurial engineer are listed above. We consolidate these attributes into the four defining KEEN characteristics: commercialization through engineering knowledge, customer awareness, business acumen, and societal values. In the KEEN lexicon, these four defining characteristics form the four corners of a pyramid. (See Figure 1.) The three-dimensional, four-corner pyramid metaphorically contains all engineering graduates of KEEN colleges and universities. The pyramid can be divided into three horizontal strata. The stratum at the base contains the greatest number of entrepreneurial engineers, and they are the staff engineers in all forms of companies. The middle stratum contains "intrapreneurial" engineers in large- and medium-sized companies. The top stratum contains the entrepreneurial engineers, those who are personal stakeholders in start-up companies.

Attribute	Rationale
Integrity	Committed to working for the benefit of the customer as promised.
Tenacity	If a new product opportunity were obvious, someone would have introduced it. All entrepreneurs face those who say "It can't be done." With technology-based products, this attitude is amplified. Tenacity is the stick-to-it-ness that finally gets to the endpoint desired in the face of doubt.
Ethics	Doing the right thing and doing the thing right for the benefit of the customer.
Creativity	The ability to synthesize, not just analyze, new-to-the-world product concepts vis-à-vis Daniel Pink's *A Whole New Mind* (2006).
Intuition	The prescience to see a market opportunity and leverage technology appropriately to fill an unmet need.
Engineering Fundamentals	A deep knowledge of technology that will create benefit in the marketplace through an appropriate feature-rich set of customer-desired attributes.
Commercialization Engineering	Entrepreneurial engineers know the steps of product commercialization from concept creation to production standardization.
Lifelong Learning	Technological advances in developed and developing countries will afford new ways of meeting unmet market needs. Entrepreneurially minded engineers will need to remain current on the newest forms of technology that can be leveraged to provide new benefits for their customers.
Societal Values	The engine that keeps an economy healthy is free enterprise. We see frequently that dishonest gain can also be the downfall of free enterprise. Entrepreneurially minded engineers will place value on ethical behavior and will exhibit the virtues of personal character such as honesty, integrity, persistence, and good citizenship.
Communication Skills	New ideas require explanation. Entrepreneurially minded engineers will be able to communicate the story behind their new ideas to convince key stakeholders to invest in and customers to accept their new ideas.
Change Agent	The ability to adapt new technology and approaches to new market needs will require entrepreneurially minded engineers to not only accept corporate change but be instrumental in defining the change.

Table 2. Rationale of Entrepreneurial Attributes

Staff engineers will understand the importance of supporting their entrepreneurial company but, in general, they will be comfortable with the typical problem-solving role engineers often serve. They may be characterized as being generally risk averse.

Intrapreneurial engineers will always be looking for ways to change the rules of competitive engagement through new product designs, redefining the boundaries of competition by leveraging core technologies into new business segments, or creating entirely new markets through the application of disruptive technologies (Hamel and Prahalad 1994).

Engineers who are entrepreneurs will be driven, as all entrepreneurs are, to fill an unmet need in the marketplace through new product concepts. Entrepreneurial engineers will have the advantage of knowing how to leverage new technology to create products their customers desire but don't yet know that they want. They will be comfortable with risk management, and they will be tenacious in their quest while others remain skeptical. (If a new product concept's success was obvious, someone would have already commercialized it.)

The four entrepreneurial characteristics are the following:

A KEEN understanding of the technical fundamentals of engineering

All engineering programs in America that are accredited by the American Board of Engineering and Technology (ABET) can demonstrate they teach the technical fundamentals of engineering. However, there is a difference between teaching the theory of engineering and the practice of engineering. KEEN engineering schools focus on both the theory and practice of engineering. In the practice of engineering, the creative side of engineering will be developed (i.e., innovation) as well as the practical side of engineering, viz., engineering product concepts for commercialization. Most senior capstone projects focus on first-article, proof-of-concept designs. KEEN programs will teach in all engineering disciplines the elements of design verification, characterization, qualification, validation, and standardization for long-term sustainability.

A KEEN understanding of customers

Entrepreneurial engineers will first think in terms of product benefits for their internal and external customers before they think in terms of design features. Thus, customer awareness will be the focus of entrepreneurial engineers. They will know how to ask probing questions and, more importantly, how to actively listen.

A KEEN understanding of business

Entrepreneurial engineers will have the necessary business acumen to support the organizations in which they work. Business acumen includes understanding the basics of financial management, but it also includes understanding organizational management including cross-functional team effectiveness, interpersonal communication skills, and conflict resolution.

A KEEN understanding of societal values

In our increasingly "flat" world, all engineers will need to be aware of how their work is connected to people throughout the world, particularly as the problems they are working to solve affect more and more people. In this context, all engineering graduates of KEEN colleges and universities will have a strong sense of service to others and will constantly be concerned with how their solutions benefit other people. They will value and help promulgate the free enterprise system, maintaining its virtues and fighting against the corrupting forces that take the focus off serving customers in lieu of serving self. Like all engineers, they will value and promote high standards of engineering and business ethics. They will possess personal character attributes typical of entrepreneurs: intuition, integrity, tenacity, courage, honesty, and good citizenship.

How are These Attributes Instilled in Engineering Students?

Figure 1 is a high-level diagram of the KEEN Theory of Change. That is, this is a process flow chart of how the entrepreneurial mindset will be instilled in engineering graduates at KEEN engineering colleges. Kern Family Foundation support is used to catalyze change at member colleges of the KEEN Network. However money, in any amount, will not change culture. Culture change must come from within; it needs to be intrinsic. Thus, the institution will desire to change to align itself with the KEEN mission. This requires administration's commitment to change. Faculty will not necessarily change by mandate of the university's administration so they, too, will need to drive a grass-roots cultural shift. The change also needs to be supported by the greater community of the university or college.

With these prerequisites, pedagogical change will begin. Fundamentally, at the heart of it all, instilling the entrepreneurial mindset needs to be systemic to the engineering education experience. No single course needs to be added to the already filled general degree requirements. Instead, the entrepreneurial engineering attributes can be included in class discussions, in case studies, in guest lectures, and in problem examples. Many colleges and universities today do an exemplary job of instilling entrepreneurial engineering in their course curricula: MIT, Stanford, and Rose-Holman are some often-touted examples.

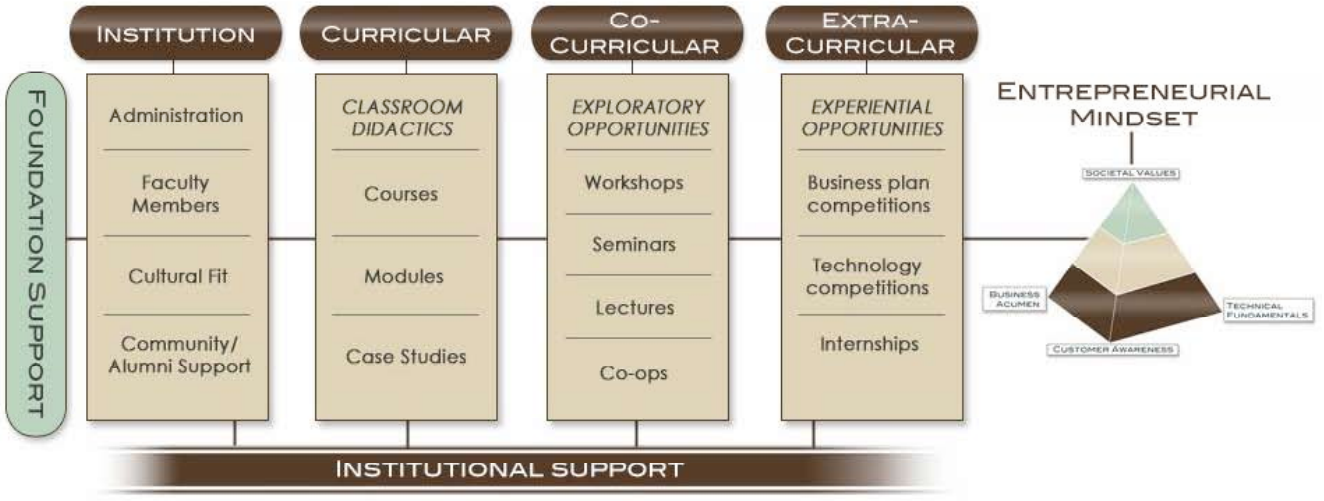

Figure 1. The KEEN Theory of Change is the process by which entrepreneurially minded engineers are formed at undergraduate engineering programs offered by KEEN colleges and universities.

Co-curricular experiences are further means to instill the entrepreneurial mindset outside of classroom didactics. These are educational opportunities that offer college credit. They may be workshops, seminars, lecture series, or cooperative work experiences.

Finally, extra-curricular experiences offer no college credit, but they are present in every academic institution. They may take the form of competitions or internship work experiences. They might be field trips or boot camps. They may be opportunities to attend professional meetings like the NCIIA, ASME, IEEE, or SAE meetings.

Underlying all of these pedagogical initiatives is the sustaining financial support of the institution. The sources of funds may come from a variety of foundations and corporations. As part of Kern funding, the institution must demonstrate that they will be able to sustain this paradigm shift into the future by securing the necessary financial resources beyond Kern funding.

How Do We Know if We Are Meeting Our Goals?

The KEEN mission is in its earliest phases. Although the goal is to affect every engineering student in KEEN engineering colleges, the goal has not yet been met in most to the colleges receiving Kern Family Foundation support. Assessment is and will continue to be a critical part of the program. Fundamentally, the ultimate goal is to assess student attitudes and behaviors to determine if they align with the attributes listed in Table 2.

However, change is dependent on the drivers of change in an academic institution, viz., the faculty, staff, and administration. Until sufficient time passes to measure the ultimate outcomes in the attitudes and behaviors of KEEN engineers after graduation, we will assess more immediate inputs and outputs within the institutions themselves. Moreover, we will assess the base of support the institutions develop along with alliances for support. Table 3 lists the variables we hope to see changed in order to affect the listed outputs.

Inputs	Support Base	Alliances	Student Experiences	Outputs
# of faculty development opportunities	# of KEEN conferences administrators attend	# of faculty & student collaborations across engineering disciplines	# of integrated experiential opportunities	Student pre- and post- survey results
Entrepreneurial minor (y/n)	# of faculty members speaking at KEEN conferences	# of faculty & student collaborations across other disciplines	# of integrated exploratory opportunities	
Entrepreneurial certificate (y/n)	# of students participating outside of coursework	# of faculty & student collaborations across network campuses	# of students enrolled in KEEN coursework	
# of embedded courses		# of engineering faculty		
# of embedded course modules		# of business faculty		
# of faculty involved		# of other faculty		
		# of alumni involved		
		# of corporations involved		

Table 3. For each KEEN institution, annual reports are required to capture inputs, base of support metrics, alliances formed, and student experiences in order to affect the specific outputs listed.

In addition to these assessment metrics, a self-assessment rubric was developed for KEEN institutions to determine how well they see themselves developing an entrepreneurial engineering milieu in their college. Forty-two questions are asked, based on a five-point Likert scale. Based on their own assessments, a SWOT analysis is created for eleven program attributes. Strengths and Weaknesses are internal-to-the-institution factors and Opportunities and Threats are external-to-the-institution factors. The eleven SWOT attributes

are:

Strengths and Weaknesses

Administration

Faculty

Students

Curriculum

Co-curricular Opportunities

Interdisciplinary Synergies

Opportunities and Threats

Extracurricular Opportunities

Alumni

Corporate Involvement

Extramural Funding

Networking

The complete set of 42 rubrics cannot be shared in this paper due to length restrictions, but an example of two rubrics for KEEN program fit as far as the students it affects are as follows.

On a scale of 1 – 5 with 5 best, how many engineering students are reached with the entrepreneurial-mindset courses?

1 = 10 – 20 engrg students over four years	2 = 20 – 50 engrg students over four years	3 = 50 – 100 engrg students over four years	4 = 100 – 500 engrg students over four years	5 = >500 engrg students over four years

On a scale of 1 – 5 with 5 best, what percentage of all engineers does this number represent? (1 = 0-20%, 2 = 21 – 40%, 3 = 41 – 60%, 4 = 61- 80%, 5 = >80%.)

1 = ≤ 20% of engrg students and/or only seniors	2 = 20 – 40 % of engrg students and/or only seniors	3 = 40 – 60 % of engrg upper classmen	4 = 60 – 80% of students over the course of four years	5 = 80 – 100 % of students over the course of four years

These two rubrics, among others, address student attributes in the eleven program attributes.

Length restrictions do not allow a full disclosure of how the forty-two rubrics roll up into a numerical score for the eleven program attributes. However, to demonstrate an example, the assessment of students is listed below.

Students:

1 = Resistant to acquiring any knowledge of intra- and entrepreneurial precepts. They are uninvolved in any efforts to learn about entrepreneurial engineering.

2 = Only a few participate in entrepreneurship classes and entrepreneurship co-curriculars

3 = Participation in moderate levels in classes and co-curricular activities. Talk the talk but don't walk the walk. Talk only in terms of being their own bosses to generate personal wealth. Participate mostly in senior year entrepreneurial activities.

4 = Interest in entrepreneurship classes throughout their college career. Attend co-curricular activities regularly. Participate in extracurricular activities such as competitions and internships.

5 = Set the standard entrepreneurship participation including advocacy for entrepreneurship education and opportunities, present papers at professional meetings, recruit new students to their college, acknowledge Kern support.

Similar scales are articulated for the other ten attributes. The evaluation of the program is conducted by the principal investigators, Kern fellows, and administrators of the college. An assessment creates a tally of the eleven attributes that might appear as seen in Table 4.

Since the 42 rubrics are divided among the eleven attributes, an integer number on the scale of one to five is not likely for any of the eleven attributes. The dividing line between a strength and weakness was arbitrarily set as 3.75. (*See Table 4.*)

At the onset of a new program, one would assume that an engineering college might have only a few program strengths while the others represent weaknesses. Clearly, if a college was strong in all eleven attributes, it would need no infusion of financial support to catalyze change; no change would be required. On the other hand, over the years, one would expect that weaknesses would move to strengths with the combined efforts of all involved.

Administration	Weakness	2.5	
Faculty	Weakness	3.4	
Students	Weakness	2.5	
Curriculum	Weakness	3.2	
Co-curriculars	Weakness	3.0	
Interdisp. Synergies		3.8	Strength
Extracurriculars		3.8	Strength
Alumni	Weakness	2.0	
Corporate Involvement		4.0	Strength
Extramural Funding		4.0	Strength
Networking	Weakness	2.7	

Table 4. A typical result from a self-assessment of a college's entrepreneurial engineering pedagogy is shown. The cut-off between a strength and weakness is an average numerical score of 3.75.

Assessment is not left to institution staff alone. Foundation staff also independently assesses each

program using the same 42 rubrics. Comparisons are made between the institution's self-assessment and the Foundation staff assessment. Any differences are worth discussing by Foundation and college representatives. Differences can be for two reasons: i) the institution is overly critical or overly confident of itself with respect to any of the attributes, or (ii) Foundation staff is unaware of the strengths of a college. For the latter situation, the discussion between college staff and Foundation staff gives the college an opportunity to tout its strengths in specific terms.

Another benefit of this process is to encourage university administration and faculty to speak with each other in the self-assessment process concerning their effort to change their pedagogy to instill the entrepreneurial mindset in engineering. As stated earlier, there is no advantage to overstating a college's position. Thus, the value of this process is not necessarily the specific set of numbers, but it is in the process of agreeing upon the set of numbers. The Foundation will accept only one integer number for each of the 42 rubrics, forcing consensus at the college as to where they stand in the process.

The Value of the Network

Each college will have its own set of strengths and weaknesses, as well as opportunities and threats, just as each institution will have its own set of core competencies. (Core competencies represent the unique bundle of skills and technology that differentiate one college from others.) The value of having a network of colleges is that a specific engineering college may benefit from the core competencies of the other network colleges. Through cooperation, the strengths of a particular college can be used by the others to either avoid duplication of capital expenses or as a model for others to emulate. The true value of the network is not what colleges receive from one another but what they give to one another. The network creates a virtual campus with the collective intellectual capital of the combined faculty. The network also brings together the combined capabilities of its students. In this panel session, five of the KEEN colleges (see asterisked colleges in Table 1) will present an example of their core competencies and how they may share them with the remaining colleges in the network.

Conclusion

The KEEN Network is only in its formative years. Not all engineering students have yet been introduced to the entrepreneurial mindset. Not all faculty members are convinced yet that instilling the entrepreneurial mindset is a necessary cultural change for their college. Not all administrators have even heard about KEEN, let alone support the paradigm shift it is attempting to catalyze. However, at all KEEN colleges there is a necessary cadre of administration and faculty who are committed to facilitating the cultural and pedagogical shift necessary to instill the entrepreneurial mindset. They meet together as a network of colleges at least twice a year. Many meet in regional meetings. They learn from each other. They share with each other. They support each other.

If a college or university is not in alignment with the KEEN vision, if it is not willing to contribute to the network, it does not remain in the network through sustained financial support. Through self-assessment and other means, a significant amount of accountability is expected by the Foundation and by peer institutions with one another.

Acknowledgments

The Kern Family Foundation seeks to enrich the lives of others by promoting strong pastoral leadership, educational excellence, and high quality, innovative engineering talent. The KEEN Network is indebted to the vision and inspiration of the Kern Family Foundation's founders, Drs. Robert D. and Patricia E. Kern, and to the leadership of the Foundation's president, Mr. James Rahn. The author is deeply indebted to Ms. Kristen Mekemson, Research Associate at the Kern Family Foundation, for her work in coordinating the many details of facilitating a network of colleges and for being a professional liaison to all of them. The

author is also grateful for the administrative support of Ms. Karen Cartwright.

References

Goldberg, David E. 2006. *The entrepreneurial engineer.* Hoboken, NJ: John Wiley & Sons.

Hamel, Gary, and C. K. Prahalad. 1994. *Competing for the future*. New York: Harvard Business School Press.

Miller, John J. 2005. *A gift of freedom: How the John M. Olin Foundation changed America*. San Francisco, CA: Encounter Books.

Peters, Thomas J., and Robert H. Waterman. 1982. *In search of excellence*. Las Vegas, NV: Harper & Row.

Pink, Daniel H. 2006. *A whole new mind: Why right-brainers will rule the future.* New York: Penguin Group.

Pistrui, David, Jeffrey Blessing, and Kristen Mekemson. 2008. Building an entrepreneurial engineering ecosystem for future generations: The Kern Entrepreneurship Education Network. Paper presented at ASEE Annual Conference, Pittsburgh, PA.

Treacy, Michael, and Fred Wiersema. 1995. *The discipline of market leaders*. Toronto: Addison Wesley.