



BISHOP
GROSSETESTE
UNIVERSITY

[BG Research Online](#)

Rae, D. and Melton, D. E. (2017). Developing an entrepreneurial mindset in US engineering education: an international view of the KEEN project. *The Journal of Engineering Entrepreneurship*, 7(3).

This is the final published version of an article published by The Journal of Engineering Entrepreneurship on 28 February 2017 at http://www.jeenonline.org/Jeen_Vol7_Num3.html

Copyright is retained by the authors and/or other copyright holders.

End users generally may reproduce, display or distribute single copies of content held within BG Research Online, in any format or medium, for personal research & study or for educational or other not-for-profit purposes provided that:

- The full bibliographic details and a hyperlink to (or the URL of) the item's record in BG Research Online are clearly displayed;
- No part of the content or metadata is further copied, reproduced, distributed, displayed or published, in any format or medium;
- The content and/or metadata is not used for commercial purposes;
- The content is not altered or adapted without written permission from the rights owner/s, unless expressly permitted by licence.

For other BG Research Online policies see <http://researchonline.bishopg.ac.uk/policies.html>.

For enquiries about BG Research Online email bgro@bishopg.ac.uk.

Developing an Entrepreneurial Mindset in US Engineering Education: An International View of the KEEN Project

David Rae* and Douglas E. Melton

Abstract: *This article explains the Kern Entrepreneurial Engineering Network (KEEN) in introducing innovative approaches to undergraduate engineering degree programs in universities in the United States of America (USA). The mission is to graduate engineers with an entrepreneurial mindset to create personal, economic, and societal value.*

The article aims to (a) explain the background rationale for the KEEN network in the US industrial context, (b) describe the approach used to introduce entrepreneurship into US engineering education, and (c) assess the wider contributions of the KEEN approach to entrepreneurship education and learning in STEM subjects and beyond the USA.

The article summarizes the role and aims of KEEN in the context of entrepreneurial education in US undergraduate engineering programs. It summarizes the policy context and provides a short review of prior work in entrepreneurship education in engineering. The KEEN case study explains the developmental approach used by the project and its contribution to expanding entrepreneurship education in the context of US engineering degree programs. It introduces the entrepreneurial learning and mindset concepts developed by the project.

The scale of KEEN intervention across the USA is illustrated, showing institutional size, characteristics, interventions, and results from the project. The development of the entrepreneurial mindset and KEEN student outcomes model are outlined with learning points. Transferable learning points from the development work are identified, summarizing the KEEN experience in relation to wider issues at social, institutional, and industry levels and their implications for engineering and STEM subjects.

1. Introduction

This article outlines the work of the Kern Entrepreneurial Engineering Network (KEEN) in introducing innovative approaches to undergraduate engineering degree programs in universities in the United States of America (USA) since 2005. The approach adopted by KEEN is distinctive and has achieved significant scale and impact in entrepreneurship education in the USA, yet is little known in other parts of the world where there is now growing interest in the adoption of entrepreneurship in engineering programs. The KEEN mission is to graduate engineers with an entrepreneurial mindset who can create personal, economic, and societal value through meaningful work. The context for this work is outlined in relation both to the economic factors, which require an entrepreneurial approach to develop the future workforce for the engineering industry, and the educational arena in which entrepreneurship can act as a dynamic transformational force.

* Bishop Grosseteste University

The aims of the article are the following:

1. Explain the background and rationale for the KEEN network in the US industrial context,
2. Describe the developmental approach used in the context of entrepreneurship education,
3. Assess the wider contributions of the KEEN approach to entrepreneurship education and learning.

The article provides a short review of prior work addressing entrepreneurship education in STEM subjects and engineering; the application of the entrepreneurial university concept; and the connections with the entrepreneurial learning and mindset concepts. It then summarizes the role and aims of KEEN in the context of entrepreneurial education in US undergraduate engineering programs. The educational models developed through the KEEN project and the management of change process adopted in working to create an entrepreneurial ecosystem with the partner institutes are explored using a case study approach.

2. The context: the need for entrepreneurship education in US undergraduate engineering programs

The US and other advanced economies including the European Union (EU) experienced a period of several decades from the 1980s until the mid-2000 era when the decline of engineering and manufacturing industries was an economically accepted norm. The US lost 41% of manufacturing employment between a peak of June, 1979 and December, 2009 when it reached a low point of 8.9%, the decline having accelerated from 2000 onwards with the most severe manufacturing job losses in U.S. history (Helper, Krueger, & Wial, 2012). In the European Union, 6 million manufacturing jobs were lost between 2000 and 2012 (Lichtblau et al., 2013).

The export of manufacturing capacity and employment to Asian countries, especially Taiwan, China, and India, was driven by cost-competitiveness in response to major industrial competitors in the Far East. This period saw major reductions in the scale and employment within large-scale manufacturing industries, accompanied by a decline in the apparent attractiveness of careers in engineering, technology, and manufacturing. There was a perception that these industries were in terminal decline and that career opportunities would be insecure, poorly rewarded, and less interesting than alternatives. However, US student recruitment to science and engineering degree programs continued to increase in this period, although there were concerns regarding high school levels of achievement in math and science subjects as a factor affecting the number of students qualified for science and engineering programs. There have been campaigns to attract students and to raise standards in science, technology, engineering, and math subjects (STEM) in both the US and the United Kingdom (UK).

There has been a growing realization, however, that simply exporting manufacturing production and activities is neither inevitable nor sensible in every case. Non-US based corporations such as Hitachi, Siemens and Hyundai demonstrated their ability to achieve long-term success, profitability, and competitiveness in multiple industry sectors, including transportation, energy, and domestic and industrial equipment. The loss of high-value adding engineering centers and employment had major effects on the gross domestic product, taxation revenues, and prosperity at local, state, and national levels. The changing international security also reinforced the need to recognise high technology manufacturing in a number of industry sectors as strategically vital.

It is increasingly evident that a healthy, competitive, and secure economy requires high levels of investment in science, technology, and engineering. In a study on manufacturing in the EU, Lichtblau et al. (2013) show that the manufacturing share of economic Value Added (VA) declined in the EU from 30% to 15% between 1970 and 2012 and in the USA from 25% to 13% in the same period, with

Developing an Entrepreneurial Mindset in US Engineering Education: An International View of the KEEN Project

corresponding declines in employment. This study supports a European policy objective to return this rate to 20%. It showed the US as having the most competitive economy overall for manufacturing in 2013, based on strengths in governance, innovation, education, infrastructure, capital markets, and internal market, but with lower-cost competitors narrowing this lead. In the US, a study for the Brookings Institute (Helper et al., 2012) argued that American manufacturing matters because it makes crucial contributions to four important national goals: providing high-wage jobs; driving commercial and service sector innovation; reducing the national trade deficit; and contributing to environmental sustainability.

It is also increasingly recognized that innovation is an essential driver for competitiveness through achieving higher added value in technologies and services. While Drucker (1985) demonstrated the fundamental connections between innovation and entrepreneurship, the philosophy of much engineering education tended towards a “fitness for purpose.” This approach emphasized compliance within K-12 through educational testing standards and at the university level with industry-driven accreditation standards, rather than on the stimulation of creative thinking and innovation. There was also a tendency to overlook the fundamental importance of STEM disciplines in creating the knowledge and technologies which enable radical entrepreneurial innovations in industries such as personal computing and telephony, healthcare, transportation, and many other fields. So while young people were increasingly aware of entrepreneurship and rapid-growth startups in computing application and internet technologies, and used them on devices made by Apple and others, they did not necessarily associate this type of “cool” entrepreneurship with the enabling science and technology base. There is also a tendency to converge these different aspects of knowledge within the STEM framework, which, while essential to create the science and technology base, is incomplete without entrepreneurship or intrapreneurship. Those in science and math are generally concerned with the advance of theoretical knowledge, while those in technology and engineering are applied to create value from known processes, materials, and resources. Traditional studies in STEM eschewed entrepreneurship, celebrating the theoretical and scientific discovery rather than the iterative process of translating a discovery into an economically impactful and technically feasible result.

The importance of entrepreneurship has been increasingly acknowledged as a national imperative. As Byers, Seelig, Sheppard, and Weilerstein (2013) observed, “The White House has emphasized entrepreneurship as a means of driving innovation: in addition to improving STEM education, President Obama’s strategy for American innovation calls for an investment in high-growth and innovation-based entrepreneurship to drive the US economy” (NEC, 2011).

As a result of these macro-factors at economic, political, social, educational, and technological levels, it became apparent that educators faced major challenges in repositioning STEM, and particularly engineering education in relation to the changing expectations of industry, society, and young people. The introduction of entrepreneurship into engineering education is seen in this context. Taks, Tynjala, Toding, Kukemelk, and Venesaar (2014) reported that the 2011 annual report of the European Society for Engineering Education (SEFI, 2012) emphasized the importance of developing mindsets toward creativity, innovativeness, and entrepreneurship in universities. In 2008, the US National Academy of Engineering (NAE, 2008) identified 14 Grand Challenges for Engineering in the 21st Century. These Grand Challenges are a call to action for society’s attention to opportunities and challenges affecting quality of life. The program includes entrepreneurship as one of the five development ideals for participating students. It was initially available to engineering students at twenty institutions; in April 2015, 122 institutions committed to increasing it to include 20,000 engineering students over the next decade.

Entrepreneurship and innovation in science, technology, and engineering curricula are not new; Institutes of Technology and technology oriented universities, such as MIT and Stanford, had taught them for many years, but they were more evident in such “hotspots” and much less so in the scale, accessibility, cultural engagement, and the student appeal which are required. The movement towards universities at the heart of entrepreneurial ecosystems (Graham, 2014), entrepreneurial universities (Clarke, 1998; Etzkowitz et al., 2008) and recently innovation districts (Katz & Wagner, 2014) all highlight the central roles which universities can play in energizing the social and institutional connections required for knowledge exchange, innovation, and entrepreneurship at city-regional, national, and industrial levels.

3. Entrepreneurship education: the policy context

Recently, as Rae et al. (2014) demonstrated, there has been significant activity at the international level to connect entrepreneurship education with economic development (World Economic Forum, 2009), to establish activity levels (Martinez, Levie, Kelley, Rögnvaldur, & Schött, 2010) and to assess its effects and impact (EU, 2012). The United Nations Conference for Trade and Development provides clear policy guidance on enhancing the role of education in the entrepreneurship ecostructure (UNCTAD, 2012).

There have been numerous reports in this direction by the European Commission, 2006; UNCTAD, 2012; the U.K. Quality Assurance Agency for Higher Education, 2012; and OECD (Lackéus, 2015). The QAA (2012) work proposed a model of entrepreneurial awareness, capability, mindset, and effectiveness as outcomes from entrepreneurship education, which can be developed within any subject discipline. These reports evidence the recognition of the contributions of entrepreneurial learning and education, to graduates, organizations, and economies, and there is extensive research in Europe on the value of entrepreneurship education (Matlay, 2008; Rae, Martin, Antcliff, & Hannon, 2012).

There have been distinct but often connected threads of research into entrepreneurship education as a pedagogical and institutional concern and entrepreneurial learning as an opportunity-centred, naturalistic, and social interest located in businesses and the world outside the classroom (Rae, 2015). In both areas there has been increasing awareness of the need and value of weaving them together for mutual strength. Education needs to understand and to use effective “real-world” learning while educational models can inform and enrich the value of naturalistic learning experiences. Entrepreneurship in engineering offers the potential to achieve this connectivity.

Another factor playing an important part in shaping government and educational policy on entrepreneurship is the consideration of entrepreneurial universities, and the ways in which institutional policies and strategies, values, culture and actions can stimulate, support and shape entrepreneurial development within and beyond the institution (Clark, 1998) and act as an entrepreneurial ecosystem (Valdez, 1988; Mason & Brown, 2013). Etzkovitz et al. (2008) developed the triple-helix model of university, business, and government interaction, which has been highly influential in this policy development. Graham (2014) refers to the need to converge entrepreneurship and innovation at an institutional, strategic, and policy level with “grassroots” community engagement internally and externally, and with strong industry-funded research and intellectual property licensing. Science, especially technology and engineering research and education, has increasingly powerful contributions in creating value from these interactions.

While Business Schools have often formed a locus for the development of entrepreneurship education in universities, there has been increasing growth in entrepreneurship in a range of non-business subjects (QAA, 2012; Nambisan, 2015). Business graduates may be less likely to set up new

Developing an Entrepreneurial Mindset in US Engineering Education: An International View of the KEEN Project

businesses or to become self-employed than graduates in subjects such as art and new product design and development, for example. The entrepreneurship education movement has grown in pace and scale worldwide in recent years and has applications both at the generic level (for example in relation to enhancing graduate employability) and in creating new value within the specific context of the subject area or industry domain.

4. Introducing entrepreneurship into engineering education

Entrepreneurship education in STEM subjects, and particularly engineering, has become a distinct field of research, which connects engineering education with entrepreneurship and innovation (Eisenstein, 2010). However, this development has progressed separately in both Europe and the US, with few connections between the emergent bodies of knowledge evident in the literature.

In the US, Creed, Suuberg, and Crawford (2002) recommended entrepreneurship in engineering education as a new paradigm for the discipline, while Kleppe and Wang (2001) and Sullivan, Carlson, and Carlson (2001) addressed how invention and innovation can be taught in US engineering entrepreneurship programs. Standish-Kuon and Rice (2002) identified significant factors for such programs. Luryi et al. (2007) presented the results of a pilot entrepreneurship study in the context of growth within the sector, which recommended all engineering students should participate in hands-on learning with innovative engineering projects. Blessing, Mekemson, and Pistrui (2008) developed an early conceptual paper on the KEEN project as an entrepreneurial engineering ecosystem. Kriewall and Mekemson (2010) published the first educational tenets for KEEN (which have been updated in 2013 and are included in sections below). Finally, Duval-Couetil, Reeds-Roads, and Haghighi (2012) researched engineering students' involvement, attitudes, and outcomes from entrepreneurship education. They found positive indications from secondary research on the outcomes of entrepreneurship in engineering programs. Their survey revealed an unmet demand from students to learn more about entrepreneurship and to broaden the range of learning opportunities and career prospects.

There is an active critique in the US of the relevance of the engineering education system in adapting to industry and socioeconomic needs. The Bridge, a journal linking engineering and society, published a special issue in 2013 on undergraduate engineering education which featured examples of innovation in teaching and learning, including the requirement to change the school science curriculum and embody the Next Generation Science Standards (Spencer & Mehle, 2013).

The importance of “soft skills” is increasingly recognized as a key dimension of the learning process, as are practical applications of theory and learning. A contribution by Byers et al. (2013) set out the role of entrepreneurship in engineering education, citing previous studies in the field by Besterfield-Sacre, Ozaltin, Shartrand, Shuman, and Weilerstein (2011), Shartrand, Weilersteing, and Besterfield-Sacre (2010), and Zappe, Hochstedt, Kizenwether, and Shartrand (2013), who researched the attitudes of engineering faculty educators, finding that they believe the following:

“The characteristics of an entrepreneurial mindset can be learned, including the ability to act on opportunities, learn from failures, and solve problems, as well as technical, business, interpersonal, and communication skills. The way educators teach entrepreneurship is deeply influenced by their own career experiences as well as their beliefs about how people become entrepreneurs” (Byers et al., 2013).

They also reported on an Epicenter (Stanford) study of 41 US engineering schools, offering an optimistic view of the development of entrepreneurship education in engineering.

In parallel, in the United Kingdom (UK), Handscombe et al. (2008) addressed the embedding of enterprise in science and engineering, and O’Leary (2012) reported the positive benefits of entrepreneurship education and the involvement of guest speakers in engineering programs in the UK, also specifically addressing the gains in employability and practical skills acquisition. Refaat (2009) argued the need for entrepreneurship education in engineering programs in developing countries. Rodriguez-Falcon, Hodzic, and Symington (2011) adopted innovative approaches to explore intercultural entrepreneurial learning among engineering students in the UK.

Taks et al. (2014) explored engineering students experience studying entrepreneurship in Estonia, based on a socio-constructivist view of learning and integrative pedagogy. They considered the range of technical, organizational, and human skills required of engineers and the role of entrepreneurship in preparing intrapreneurs as well as entrepreneurs. They adapted an integrative pedagogy model for entrepreneurship and applied this to an engineering degree program. They identified four qualitatively different categories in which students experienced entrepreneurship education: a first step to self-directed learning, a preparation for work-life, a path to possible self-employment, and a context for developing leadership and responsibility for team achievement. They recommended that “for developing an entrepreneurial mindset, a socio-constructivist view and integrative pedagogy are very promising approaches” (Taks et al., 2014).

These studies exemplify growing interest in entrepreneurship education within engineering degree programs. They indicate the international scale of this, which started in the USA but is gathering pace in mainland Europe, the UK, and other countries. Engineering programs often exhibit practical and experiential approaches and project-based and team learning consistent with best practices in other disciplines. There is an active interest in pedagogy, and a repeated theme is the concept of “the entrepreneurial mindset as an outcome of the learning process.” The desire for development of individual aspirations, efficacy, and learning-to-learn capability through the teaching experience is evident. The aim is to develop engineers who have entrepreneurial ways of thinking and working, which they can apply within existing organizations of differing sizes and types, rather than with a sole emphasis on producing start-up founders. These themes characterize the philosophy behind the KEEN development, to which we now turn.

5. The Kern Entrepreneurship Education Network (KEEN) case

5.1. The Kern Family Foundation: inception and development of the KEEN project

The Kern Family Foundation was founded by Robert and Patricia Kern who started Generac Power Systems as a power generator manufacturing organization in Wisconsin in the United States Midwest and grew the business for five decades starting in the 1950s. During this period, they recognized the necessity for constant innovation to address competition and business change, while experiencing the deficits and consequences for manufacturing of American skill levels in science, math, and engineering. They recognized that reforming science education to encompass innovation was essential at secondary and post-secondary levels.

The Foundation has supported a K-12 program, which partners with schools to prepare students for science, engineering, and technology careers they might not otherwise have considered. Project Lead the Way (PLTW) develops problem-solving, teamwork, communication, and leadership skills to national standards, covering over 6,500 schools and 700,000 students in 50 states.

This addresses the industry’s requirement for engineers with better communication and teamwork skills and a broader understanding of how to solve real-world problems and create value in the marketplace by competing on innovation. To achieve that, the talent pool of future innovative

Developing an Entrepreneurial Mindset in US Engineering Education: An International View of the KEEN Project

thinkers and leaders with an entrepreneurial mindset needed to be renewed and strengthened. The concept of entrepreneurial mindset has developed from the original work of McGrath & MacMillan (2000) through subsequent development by others. Haynie, Shepherd, Mosakowski, and Earley (2010) defined entrepreneurial mindset as “cognitive adaptability...the ability to be dynamic, flexible, and self-regulating in one's cognitions given dynamic and uncertain task environments.” There are varying approaches and recent European thinking takes a more holistic approach, which includes affective as well as cognitive capability (QAA, 2012).

5.2. The formation of KEEN

The Kern Family Foundation established the Kern Entrepreneurship Education Network (KEEN) in 2005 with the mission to create an action-oriented, entrepreneurial mindset among engineering, science, and technical undergraduates. Mr. Kern explained his commitment to KEEN as “our vision is not just to teach students how to start their own businesses, but to prepare them to think *entrepreneurially*, particularly more broadly and deeply about how their ideas fit into their environments” (Blessing et al., 2008).

The aim was to create an *entrepreneurial ecosystem* of engineering schools that provides a strong foundation for graduate engineers to work in organizations able to compete effectively in an innovation-based economy. Ecosystems can be defined as environments with interconnected relationships influenced by a variety of factors. This took as a working definition that an entrepreneurial ecosystem “links people by vision, commitment, passion, and innovation surrounding the achievement of a common goal.” The concept of entrepreneurial ecosystem has differing definitions; as originally proposed by Valdez (1988) it referred to “the interrelationship between the entrepreneur and the economic conditions of the environment (the macro-environment)” including resources and market opportunities. Since then the notion of the “entrepreneurial university” (Clark, 1998) has significantly influenced the development and applications of this concept, as demonstrated by Graham (2014). Hence the two pillars of the KEEN initiative, entrepreneurial mindset and ecosystem, continue to evolve alongside the developmental nature of the project.

KEEN was envisaged as local sets of educational entrepreneurial actors, including both institutions and faculty members, who would participate in the larger network. When founding the network, the Kern Family Foundation aimed to create an entrepreneurial ecosystem with three attributes:

5.2.1. Entrepreneurial mindset

The network aimed to identify how entrepreneurship could be introduced at member institutions. KEEN was formed by educators who wished to offer educational experiences in the development of both a professional skillset and mindset. A decision was made to integrate the professional skills of engineering taught with entrepreneurial thinking. KEEN developed the conceptualization of entrepreneurship in Figure 1, which illustrates a continuum from mindset to value creation. Entrepreneurial mindset is a precursor for entrepreneurial behaviours, intentions, or action and represents an individual's worldview: their attitudes, dispositions, motivations, and expectations. Mindset is likely to be influenced by non-cognitive and affective thinking. At the other extreme lies new business creation, either in the form of a new venture or within an existing organization.

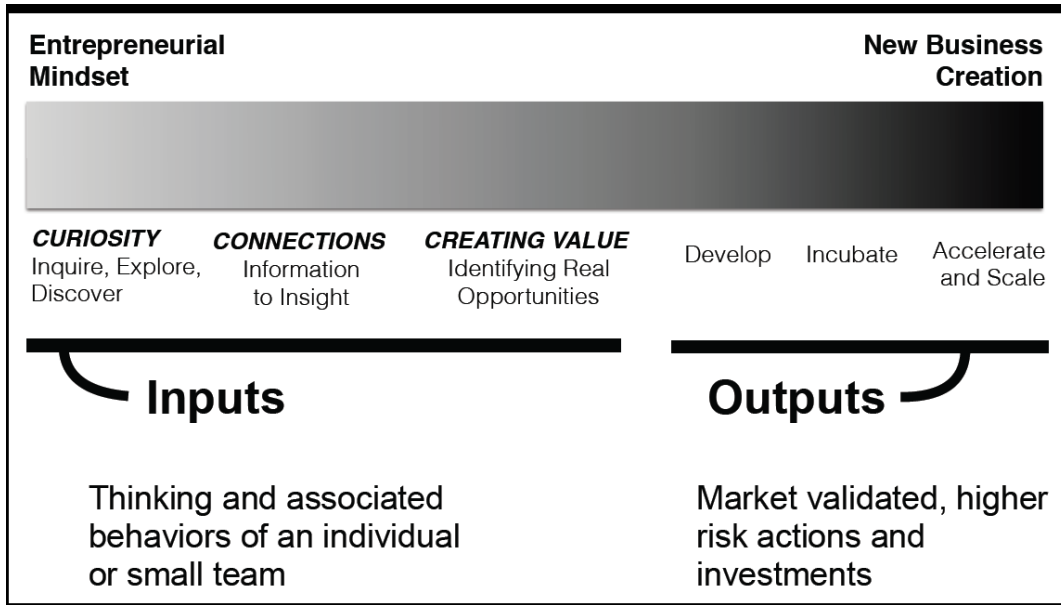


Figure 1. The entrepreneurial continuum, from mindset to business creation.

5.2.2. Engineering

While entrepreneurial behaviour may emerge from any study discipline, an innovation-based economy relies on Science, Technology, Engineering, and Math (STEM). Engineering was selected as the focus area through being closely connected to entrepreneurship by the shared goal of creating value from available processes, technology, materials, and resources. However, engineering is often associated with thought processes characterized as careful, methodical, analytical, linear, and risk aware. These are valuable characteristics, and an engineering graduate with an entrepreneurial mindset will take full advantage of these skillsets. Engineering provided a university connection for the creation of the network, which could then encourage entrepreneurial cross-disciplinary work.

5.2.3. Undergraduate Education

A network formed with higher education partners offered the important features of the multiplier effect of working with faculty members who reach many students over a long period of time, and a network of colleges and universities that could sustain itself well beyond the period of support provided by the foundation.

A decision was made to focus efforts on undergraduate education, so advanced degrees are outside its scope. By introducing interventions designed to inculcate an entrepreneurial mindset as early as freshman year, the entire academic career of a student could be framed. The decision also allowed the foundation to concentrate its efforts on a broad base of undergraduate engineers, the majority of whom would be employed upon graduation by a corporation, government, or non-profit organization. Because entrepreneurial mindset is applicable in any context, the program would foster intrapreneurship within those organizations.

The network was launched in 2005 at a meeting of private Midwestern universities: twenty received funding to develop proposals for entrepreneurship in undergraduate engineering programs. Twelve submitted proposals, eleven were funded to develop engineering entrepreneurship programs, ten completed the Phase 1 pilot stage, and eight established entrepreneurship education programs (Blessing et al., 2008).

Developing an Entrepreneurial Mindset in US Engineering Education: An International View of the KEEN Project

5.3. Growing the network

In the following decade, the Foundation worked with more than thirty-six institutions of higher education with the shared mission to foster an entrepreneurial mindset in engineering undergraduates. The network currently includes 24 active partner institutions who are developing a variety of curricular and extracurricular engineering educational programming across all engineering departments. The network of partners and faculty members is expected to continue to grow based upon the recent increase in the number of institutions who have similarly aligned interest in entrepreneurial engineering education, as demonstrated by the adoption of similar initiatives.

The network includes two types of nodes, partner institutions and faculty members. Together, the partner institutions account for more than 34,000 engineering students, approximately 6% of the US total undergraduate engineering enrolment. The foundation engaged with these institutions through the process described in the next section. Figure 2 and Table 1 show the penetration into the engineering education system of the KEEN project across the USA.

5.4. The KEEN pedagogy and academic development

The KEEN strategy includes a coherent approach to institutional change. The network promotes a model of systemic program change (Bolman & Deal, 2008), which addresses the perspectives of multiple stakeholders. A theory of change model, typical of philanthropic organizations, guides the foundation by building organizational capacity and creating strategic alliances. The first area strengthens each node of the network, while the second builds critical relationships between each node. Progress in both areas is vital in the development of an active, engaged, and vibrant network of both types of nodes, institutions, and faculty members. The foundation assists the network nodes in helping to develop the shared mission, strategies, and platforms necessary to create sustainable impact on engineering education lasting beyond the lifetime of the foundation.

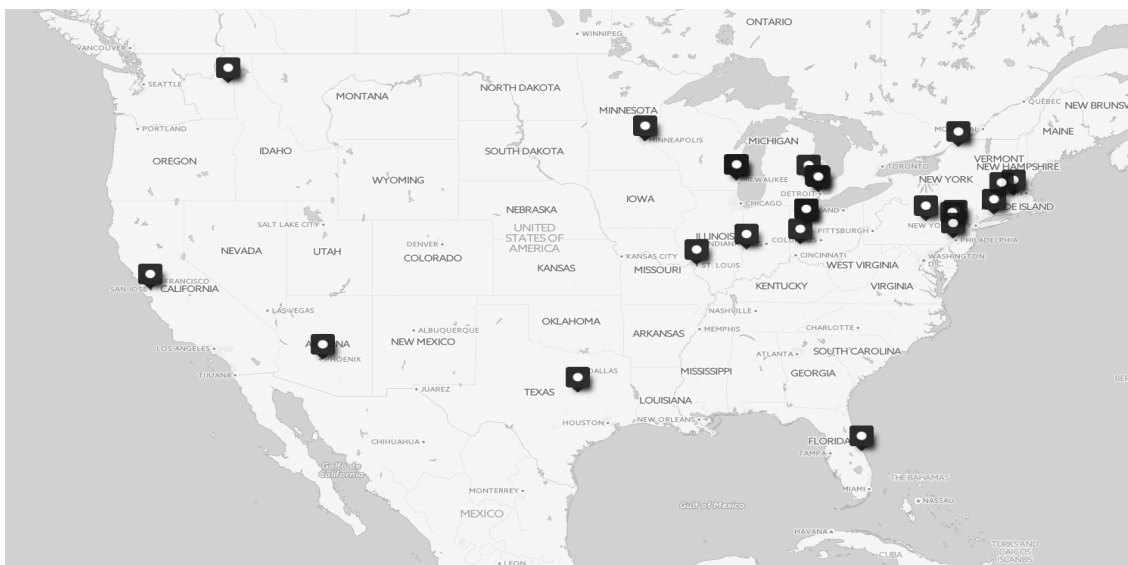


Figure 2. Current KEEN university partners

Table 1. KEEN Partners and the scale of engineering education

University or College	Location	2014 Undergraduate Enrollment	Engineering Undergraduate Enrollment (Full Time)	Engineering Faculty (Teaching FTE)
Arizona State University	Tempe, Arizona	67507	8374	276
Baylor University	Waco, Texas	13859	1117	37
Bucknell University	Lewisburg, Pennsylvania	3565	705	68
Clarkson University	Potsdam, New York	3247	1721	81
Florida Institute of Technology	Melbourne, Florida	3636	1875	100
Gonzaga University	Spokane, Washington	4837	841	46
Kettering University	Flint, Michigan	1684	1324	62
Lafayette College	Easton, Pennsylvania	2502	706	45
Lawrence Technological University	Southfield, Michigan	2798	624	51
Lehigh University	Bethlehem, Pennsylvania	5062	2110	123
Marquette University	Milwaukee, Wisconsin	8410	1066	60
Milwaukee School of Engineering	Milwaukee, Wisconsin	2596	2010	82
Ohio Northern University	Ada, Ohio	2854	447	23
Olin College of Engineering	Needham, Massachusetts	350	332	40
Rose-Hulman Institute of Technology	Terre Haute, Indiana	2280	2065	114
Saint Louis University	St. Louis, Missouri	8687	604	28
Santa Clara University	Santa Clara, California	5486	946	71
University of Dayton	Dayton, Ohio	8554	1672	71
University of Detroit-Mercy	Detroit, Michigan	2788	159	33
University of New Haven	New Haven, Connecticut	5048	636	62
University of St. Thomas	St. Paul, Minnesota	6240*	581	22
Villanova University	Villanova, Pennsylvania	6927	1053	83
Western New England University	Springfield, Massachusetts	2732	595	31
Worcester Polytechnic Institute	Worcester, Massachusetts	4235	2818	112
TOTALS		175884	34381	1721

Data from 2014 ASEE Engineering Data Management System and *2015 university reporting. In 2014, undergraduate full-time enrollment in U.S. bachelor's of engineering programs was reported as 569,274 (Yoder, 2014).

In each institution, curricular change requires excellent leadership at all levels: students, faculty, deans, provosts, and presidents. Leaders may be visionary deans, and faculty members emerge who successfully translated the broad goals of the KEEN framework into the topics they teach, using new pedagogical methods for delivery and assessment. Many champions have become faculty leaders within KEEN, persuading their peers to create sustainable and systemic change around entrepreneurial concepts new to the engineering subject base. KEEN has also supported new faculty appointments to fill entrepreneurial skills gaps.

Faculty member involvement within whole-university KEEN initiatives has reduced departmental barriers, establishing cross-disciplinary and inter-departmental relationships and collaborative work that would not otherwise have developed. For example, at Santa Clara University, the cross-

Developing an Entrepreneurial Mindset in US Engineering Education: An International View of the KEEN Project

disciplinary impact of the KEEN program has influenced the entire university's learning objectives and master plan.

Beyond organizational structure, it is important to recognize political and reward value systems. Some KEEN partners overtly value participation in the KEEN program in the faculty tenure and promotion process. Recognizing that faculty members need a publication channel for their educational innovations in entrepreneurial engineering, the foundation helped establish the dedicated, independent, peer-reviewed journal, *The Journal of Engineering Entrepreneurship (JEEN)*.

5.5. Entrepreneurial mindset: curiosity, connections, creating value

The purpose of the KEEN program is to instill an entrepreneurial mindset in graduates. Unlike a skillset that provides students with an ability to behave in a certain way or perform a particular task, a mindset is composed of attitudes, motivations, and dispositions. With the goal of investigating how mindset can be taught and learned in an educational setting, members of KEEN created a framework to describe the shared program goals. The KEEN framework is a document which describes desirable program and student outcomes and is used by each participant in the network.

Between 2005 and 2012, the KEEN framework grew to include elements from the foundation's leadership; contributions from many educators within KEEN; and scholars in entrepreneurship such as Drucker (1985) and Timmons (1989), among others. As a result, it included varied lists of entrepreneurial traits, guiding program principles, student outcomes, and assessment methods. In 2013, the Foundation created a simplified, but flexible framework to define an entrepreneurial mindset with a minimum set of attributes, as shown below.

Individuals with an entrepreneurial mindset

- have an insatiable, dispositional curiosity to understand the changing world and its technical, societal, and economical aspects of problems, solutions, and opportunities;
- make connections from many sources of information to enable insights and the development of creative solutions;
- focus on creating value, broadly defined as value for others—this may be economic value but, importantly, it also includes societal and personal value.

This set of attributes is known within the network as the 3Cs of entrepreneurial mindset. Curiosity, connections, and creating value have become three categories for collecting related and specific student learning outcomes included in objectives of programs of study, assignments, modules, and courses.

5.5.1. Student learning outcomes.

With the 3Cs acting as organizing categories, a set of outcomes can be added. The foundation has "seeded" the set with two in each category, to which members may add the set of outcomes for their own programs. A description of the student learning outcomes follows:

Entrepreneurially minded individuals have

Curiosity

1. demonstrate constant curiosity about our changing world
2. explore a contrarian view of accepted solutions

Connections

3. integrate information from many sources to gain insight
4. assess and manage risk, e.g. interconnected ramifications

Creating value

5. identify unexpected opportunities to create value
6. persist through and learn from failure, essential when iterating using stakeholder feedback

KEEN partners have adopted the 3Cs with interpretations by individual faculty members or an interpretation suitable for institution-wide implementation and assessment, including additional descriptions of associated student behaviors or learning processes.

5.5.2. Complementary Skillset

Effective individuals connect their mindset with a complementary skillset. An entrepreneurial engineer has complementary skills, such as the ability to design, analyze, create a prototype, validate a model, and work on a team. These, plus additional outcomes listed below, can be compared with the graduate entrepreneurial outcomes defined by the UK QAA (2012).

- identify an opportunity
- define benefit and value
- investigate a market
- create a preliminary business model
- evaluate feasibility, viability, and desirability
- quickly test value proposition
- engage stakeholders early
- assess policy and regulatory issues
- communicate solutions in economic terms
- communicate in terms of societal benefits
- validate market interest/stakeholder sentiment
- develop partnerships
- build teams
- identify supply chains
- identify distribution channels
- protect intellectual property

5.5.3. Entrepreneurially Minded Learning (EML)

The entrepreneurial mindset and skillsets are developed through educational interventions designed according to the KEEN framework. Entrepreneurially minded learning (EML) is an emergent pedagogy which resembles problem-based learning (PBL) and Design Thinking, but emphasizes opportunity recognition and value creation for stakeholders. This is comparable with the Opportunity-Centred Entrepreneurship methodology (Rae, 2015). Using the 3Cs, EML emphasizes opportunities and impact, while PBL begins with problems, and Design Thinking begins with empathy. Educational innovators in KEEN are developing new methods for EML by experimenting in traditional educational environments, which address the challenges of teaching both fundamental principles and simultaneously affording the discovery, experimentation, failures, and directional pivots which promote an entrepreneurial mindset.

For example, thermodynamics is taught in Western New England University by creating assignments and projects that permit experimentation, conflict, and learning from failure. A final course project creates a competitive environment between student groups acting as energy providers who design energy generation systems, which include supply chain and distribution factors. The realistic competition promotes entrepreneurial working.

6. Conclusions: learning points from KEEN for engineering education

Since its inception, KEEN has had a consistent mission, but has also experienced classic start-up behaviors, requiring experimentation, adaptation, and pivots, notably in identifying the salient elements of entrepreneurial mindset. Network building around a shared mission has been the key to

Developing an Entrepreneurial Mindset in US Engineering Education: An International View of the KEEN Project

the initiative's success and vitality over the past decade, while success in the next decade will depend on results and sustainability of the network.

As with similar initiatives, the impact on the economy and society is difficult to determine with meaningful measures. At present, the network does not have longitudinal studies of resulting business creation, whether via start-ups or through intrapreneurial enterprises. The focus over the past decade has been on program definition and implementation. Even if this remains a subject over the next several decades, economic outputs are notoriously difficult to measure and validate. Faculty members and institutions participate within KEEN, acknowledging the difficulty and delay in "proving" the value of entrepreneurial thinking in engineering education.

The KEEN initiative has wider implications for entrepreneurship education within engineering, and possibly more generally across STEM disciplines. These may apply both within the USA and in other mature economies such as Europe. KEEN has the advantage of leadership by a private family foundation with charitable objectives and a defined lifespan. Its direction is consistent with public policy, but, operating independently from government, it is not reliant on public funding. That autonomy has enabled it to grow quickly to achieve both scale and impact. In contrast, publicly funded initiatives, such as those often found in Europe, the USA, and Canada, tend to be fixed-term over three to five years at most and can be over-directed by official concerns, which can impair their effectiveness. The KEEN investment has been relatively modest by governmental standards, yet it has achieved significant results. This suggests that entrepreneurship education can be more effective by partnering with non-governmental investors, and industry, rather than being over-reliant on public funding.

There is growing interest in the contribution of entrepreneurship in engineering education, both in the US and internationally (Duval-Couetil et al., 2012; Rodriguez-Falcon et al., 2011; Refaat, 2009). The KEEN initiative has created a model of an educational ecosystem for entrepreneurial education, which is vibrant and creative in its ability to span a large country through 24 institutions in 15 states. The activities within the network, including conferences and development events, competitions, innovation projects, and research, are creating a shared body of knowledge and practice. The ecosystem is of significant educational and institutional value, and is likely to be a major factor in the sustainability of the initiative. The individual institutions and the participating faculty have a strong sense of membership, continuity and ownership in the network, which is evident through the activities featured in the website: <http://www.engineeringunleashed.com>.

The topic of entrepreneurship education in engineering is significant, in relation to economic, technological, industrial, and pedagogical interests. Future research and development of this topic should take an international approach, so that innovations such as the KEEN project can inform work in European and other countries, and to enable North American practices similarly to be informed by best practices worldwide. The growth of activity and discovery-centred approaches to entrepreneurial learning, the role of entrepreneurial teams, and innovation and intrapreneurship within larger organizations are all themes which are influential internationally and need to be connected to make the greatest contributions to education, economy, and society.

In this way, the value of the KEEN initiative deserves to be better known to the education, industry, and policy communities beyond the USA, which face comparable challenges. The developmental work on education, pedagogy, entrepreneurial mindset and skills, have many points of reference to those in other countries. We hope the case can prompt learning and exchange of knowledge in engineering and STEM entrepreneurship education and practices at an international level.

References

- Besterfield-Sacre, M., Ozaltin, N.O., Shartrand, A., Shuman, L.J., & Weilerstein, P. (2011, June). Understanding the technical entrepreneurship landscape in engineering education (AC 2011-1729). Paper presented at the 2011 Annual Conference and Exposition of the American Society for Engineering Education (ASEE), Vancouver BC.
- Blessing, J., Mekemson, K., & Pistrui, D. (2008, June). Building an entrepreneurial engineering ecosystem for future generations: The Kern Entrepreneurship Education Network. Paper presented at 2008 Annual Conference & Exposition, Pittsburgh, Pennsylvania. Retrieved from: <https://peer.asee.org/3488>
- Bolman, L.G., & Deal, T.E. (2008). *Reframing organizations: Artistry, choice, and leadership*. San Francisco, CA: Jossey-Bass.
- Byers, T., Seelig, T., Sheppard, S., & Weilerstein, P. (2013). Entrepreneurship: Its role in engineering education. *The Bridge*, 43(2), 35–39.
- Clark, B. R. (1998). *Creating entrepreneurial universities: Organizational pathways of transition*. Oxford: IAU Press/Elsevier.
- Creed C. J., Suuberg, E. M., & Crawford G. P. (2002). Engineering entrepreneurship: An example of a paradigm shift in engineering education, *Journal of Engineering Education*, 91(2), 185–195.
- Drucker, P. (1985). *Innovation and entrepreneurship*. London: Heinemann.
- Duval-Couetil, N., Reed-Rhoads, T., & Haghighi, S. (2012). Engineering students and entrepreneurship education: Involvement, attitudes and outcomes. *International Journal of Engineering Education*, 28(2), 425–435.
- Eisenstein, E. (2010). Engineering and entrepreneurship: Creating lasting value from engineering. *Proceedings of Transforming Engineering Education: Creating Interdisciplinary Skills for Complex Global Environments*, Dublin, 1–15. doi:10.1109/TEE.2010.5508952
- Etzkowitz, H., Ranga, M., Benner, M., Guarany, L., Maculan, A.M., & Kneller, R. (2008). Pathways to the entrepreneurial university: towards a global convergence. *Science and Public Policy* 35(9), 681–695.
- European Commission. (2006). *Entrepreneurship education in Europe: Fostering entrepreneurial mindsets through education and learning*. *Proceedings of International Conference on Entrepreneurship Education in Europe*, Oslo.
- European Commission. (2012). *Effects and impact of entrepreneurship programs in higher education*. Brussels, Belgium: Entrepreneurship Unit Directorate-General for Enterprise and Industry, European Commission.
- European Society for Engineering Education (SEFI). (2012). *Annual report (2011)*. Brussels, Belgium: SEFI. Retrieved from <http://www.sefi.be/wp-content/uploads/SEFI%20Report%202011-final.pdf>
- Graham, R. (2014). *Creating university-based entrepreneurial ecosystems: Evidence from emerging world leaders*. Cambridge, MA: Massachusetts Institute of Technology.
- Handscombe, R. D., Rodriguez-Falcon, E., & Patterson, E. A. (2008). Embedding enterprise in science and engineering departments. *Education+ Training*, 50, 615–625.
- Haynie, J., Shepherd, D., Mosakowski, E., & Earley, C. (2010). A situated metacognitive model of the entrepreneurial mindset, *Journal of Business Venturing*, 25, 217–229.
- Helper, S., Krueger, T., & Wial, H. (2012). *Why does manufacturing matter? Which manufacturing matters? A policy framework*. Washington DC: Brookings Institute.
- Katz, B. & Wagner, J. (2014). *The rise of innovation districts: A new geography of innovation in America*. Washington, DC: Brookings Institute.
- Kleppe, J. A. & Wang, E. L. (2001). Teaching invention, innovation and entrepreneurship in engineering. *Journal of Engineering Education*, 90(4), 565–570.
- Kriewall, T. J. & Mekemson, K. (2010). Instilling the entrepreneurial mindset into engineering undergraduates. *The Journal of Engineering Entrepreneurship*, 1(1), 5–19.

Developing an Entrepreneurial Mindset in US Engineering Education: An International View of the KEEN Project

- Lackéus, M. (2015). *Entrepreneurship in education: What, why, when, how*. Paris: OECD.
- Lichtblau, K., Matthes, J., Fritsch, M., Bertenrath, R., Grömling, M., & Busch, B. (2013). *Industry as a growth engine in the global economy*. Cologne: IW Consult.
- Luryi, S., Tang W., Lifshitz N., Wolf G., Doboli S., Betz J., Maritato P., & Shamash Y. (2007, October). *Entrepreneurship in engineering education*. Paper presented at the T2E-10, 37th ASEE/IEEE Frontiers in Education Conference, Milwaukee, WI.
- Martínez, A., Levie, J., Kelley, D., Rögnavaldur, J. S., & Schøtt, T. (2010). *Global entrepreneurship monitor special report: A global perspective on entrepreneurship education and training*. Babson, MA: Global Entrepreneurship Research Association, .
- Mason, C. & Brown, R. (2014). *Entrepreneurial ecosystems and growth oriented entrepreneurship*. Final Report to OECD, Paris.
- Matlay, H. (2008). The impact of entrepreneurship education on entrepreneurial outcomes. *Journal of Small Business and Enterprise Development*, 15(2), 382–396.
- McGrath, R. & MacMillan, I. (2000). *The entrepreneurial mindset: Strategies for continuously creating opportunity in an age of uncertainty*. Cambridge, MA: Harvard Business School Press.
- Nambisan, S. (2015). *Embracing entrepreneurship across disciplines: Ideas and insights from engineering, science, medicine and arts*. Cheltenham and Camberley, UK: Edward Elgar Publishing.
- National Academy of Engineering (NAE). (2008). *14 grand challenges for engineering in the 21st century*. Washington, DC: National Academy of Engineering
- National Economic Council (NEC). (2011). *A strategy for american innovation: Driving towards sustainable growth and quality jobs*. Washington, DC: National Economic Council.
- O’Leary, S. (2012). HE entrepreneurship teaching and employability of scientists and engineers. *Industry & Higher Education*, 26(6), 431–442.
- Pistruì, D., Layer, J. K., & Dietrich, S. (2012). Mapping the behaviors, motives and professional competencies of entrepreneurially minded engineers in theory and practice: An empirical investigation. *The Journal of Engineering Entrepreneurship*, 4(1), 39–54.
- Quality Assurance Agency for Higher Education (QAA). (2012). *Enterprise and entrepreneurship education: guidance for higher education providers in England, Wales and Northern Ireland*. Gloucester: Quality Assurance Agency for Higher Education.
- Rae, D. (2015). *Opportunity-centred entrepreneurship*. Palgrave: Macmillan.
- Rae, D., Matlay, H., McGowan, P., & Penaluna, A. (2014). Freedom or prescription: the case for curriculum guidance in enterprise and entrepreneurship education. *Industry & Higher Education*, 28(6), 387–398
- Rae, D., Martin, L., Antcliff, V., & Hannon, P. (2012). Enterprise and entrepreneurship in English higher education: 2010 and beyond. *Journal of Small Business and Enterprise Development*, 19(3), 380–401.
- Refaat, A.A. (2009). The necessity of engineering entrepreneurship education for developing economies. *International Journal of Education and Information Technologies*, 3(2), 85–96
- Rodriguez-Falcon, E., Hodzic, A., & Symington, A. (2011). Learning from each other: Engaging engineering students through their cultural capital. *Engineering Education*, 6(2), 29–38.
- Shartrand A., Weilerstein, P., & Besterfield-Sacre, M. (2010, June). *Technology entrepreneurship programs in US engineering schools: An analysis of programs at the undergraduate level (AC 2010-666)*. Paper presented at the 2010 Annual Conference and Exposition of the American Society for Engineering Education (ASEE), Louisville KY.
- Spencer, D. & Mehler, G. (2013). Opportunities in engineering education: Pathways to better-prepared students. *The Bridge*, 43(2), 24–30.
- Standish-Kuon, T. & Rice, M. P. (2002). Introducing engineering and science students to entrepreneurship: Models and influential factors at six American universities. *Journal of Engineering Education*, 91(1), 33–39.

- Sullivan, J. F., Carlson, L. E., & Carlson, D. W., (2001). Developing aspiring engineers into budding entrepreneurs: An invention and innovation course. *Journal of Engineering Education*, 90(4), 571–576.
- Taks, M., Tynjala, P., Toding, M., Kukemelk, H., & Venesaar, U. (2014). Engineering students' experiences in studying entrepreneurship. *Journal of Engineering Education*, 103(4), 573–598.
- Timmons, J.A. (1989). *The entrepreneurial mind*. Andover, MA: Brick House Publishing.
- United Nations Conference on Trade and Development (UNCTAD). (2012). UNCTAD entrepreneurship policy framework and implementation guidance. Geneva : United Nations Conference on Trade and Development. Retrieved from: http://unctad.org/en/Pages/DIAE/Entrepreneurship/UNCTAD_Entrepreneurship_Policy_Framework.ork.aspx
- Valdez, J. (1988). *The entrepreneurial ecosystem: Toward a theory of new business formation*. Proceedings of the Small Business Institute Director's Association, Jude, University of Texas, San Antonio. Retrieved from: <http://sbida.org/Resources/Documents/Proceedings/1988%20Proceedings.pdf#page=102>
- World Economic Forum. (2009). *The global competitiveness report 2009–2010*. Geneva: World Economic Forum.
- Yoder, B. (2014). *Engineering by the numbers*. Washington: American Society for Engineering Education.
- Zappe, S., Hochstedt, K., Kisenwether, E., & Shartrand, A. (2013). Teaching to innovate: Beliefs and perceptions of instructors who teach entrepreneurship to engineering students. *International Journal of Entrepreneurship Education* 29(1):45–62.