The ICE Faculty Development Program (Integrating Curriculum with Entrepreneurial Mindset) – Then and Now

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Abstract

This evidence-based practice paper describes the creation and evolution of a faculty development program known as "Integrating Curriculum with Entrepreneurial Mindset" (ICE) that has been offered for more than ten years. The program began when entrepreneurially minded learning (EML) was in its infancy and has undergone continual improvement as a deeper understanding of what is required for effective EML has continued to evolve. More than 2000 faculty members have completed the year-long faculty development program, and five years ago, many more entrepreneurial mindset-themed workshops have been developed based on the format and successes of ICE. This paper will describe the general features of ICE (e.g., active learning stacked with aspects of EM), the changes incorporated over the years, and some of its unique qualities (such as the coaching model) that have led to its growth and success. Throughout the paper, pitfalls to avoid if implementing a similar program are presented. This paper can be presented as a traditional lecture.

Then

Instilling the entrepreneurial mindset in engineering students has become widespread in engineering education in recent years. With assistance from the Kern Family Foundation, the Kern Entrepreneurial Engineering Network (KEEN) has developed and implemented numerous workshops and faculty development programs. But why and where did it all begin?

KEEN currently consists of 63 partner educational institutions whose collective mission is to "graduate engineers with an entrepreneurial mindset so they can create personal, economic, and societal value through a lifetime of meaningful work." [1] KEEN provides access to financial and developmental resources for building quality entrepreneurial mindset education programs that engage engineering and technical students, including grants, faculty fellowships, capacity-building workshops, networking opportunities, and resources (including Engineering Unleashed, an online social and sharing resource) [1].

KEEN was founded in 2004 with only a few (<10) academic institutions, all of which were private undergraduate-focused institutions. For the first few years, the definition of entrepreneurial mindset (EM) was being developed, entrepreneurially minded learning (EML) did not exist, and student outcomes to measure EM were in flux. During faculty networking opportunities at KEEN gatherings, faculty members began to implement brief training sessions with the intention to inspire instructors to add EM content to course material. These training sessions were often only an hour, and an instructor could rotate to two or three one-hour sessions. Some of these instructors would try out the material in their courses and others would organize co-curricular activities based on the inspirations drawn from the training.

In 2009, Lawrence Technological University received a grant from the Kern Family Foundation to formalize these training sessions into a structured faculty development program. The goal was

to integrate entrepreneurial mindset into the traditional undergraduate engineering curriculum by having faculty members modify their courses. Various approaches to faculty development of teaching include workshops like the National Effective Teaching Institute (NETI) [2], virtual communities of practice [3], and longer-term interventions [4]. Lawrence Tech chose to synthesize these approaches by implementing a workshop, combined with faculty cohorts, year-long "check-ins" by the facilitators, classroom implementation, and intermittent reporting sessions. Details of the format and assessment results can be found in Carpenter et al. [5] and Gerhart & Carpenter [6], but a brief synopsis follows.

Active collaborative learning (ACL) and problem-based learning (PBL) were chosen as the primary pedagogical techniques to modify courses and instill EM because they mapped very well to the EM student outcomes. (More on this later.) Faculty members committed to a two-year development process. In year one, a faculty member would participate in a week-long ACL workshop and begin developing a module (i.e., a course activity that may be anywhere from one class period to a multi-week exercise). Faculty were grouped into cohorts based on their discipline or sub-discipline (e.g., first-year engineering design, solid mechanics, electronics, etc.). The faculty in each cohort worked together during the workshops (brainstorming and bouncing ideas off each other) and also met regularly throughout the semesters to refine course content and share successes. At the conclusion of the week-long workshop, each faculty member reported on an idea for a course module and an action plan. During the following year, the facilitators would meet with the faculty for reporting (i.e., accountability) sessions. At the end of the academic year, each faculty member would close-the-loop with a report of pluses (successes) and deltas (changes for the following course offering). During year two, the process would repeat, except now with a focus on using PBL to instill EM.

Only about 15 Lawrence Tech faculty members were invited to participate each year, so the entire process was replicated over seven years. Ultimately, more than 50 faculty members modified approximately 75% of the courses in the engineering curriculum, including traditional engineering courses and general education core curriculum courses such as those in history, literature, communication, the natural sciences, and mathematics.

While all of this was occurring, a few faculty members from other institutions were invited to join Lawrence Tech's faculty development program to modify their courses with EM. Also, the Lawrence Tech facilitators were being invited to other institutions (University of Dayton, Ohio Northern University, Saint Louis University, and Worcester Polytechnic Institute) to implement Lawrence Tech's faculty development program. Momentum of the success dictated that a KEEN-wide faculty development program should begin in 2014. Faculty at the University of New Haven and Lawrence Tech received a grant to implement a year-long faculty development program known as Integrating Curriculum with Entrepreneurial Mindset (ICE). Thirty-five faculty members representing 12 institutions participated. ACL and PBL were both offered as pedagogical techniques during the single one-week workshop held at the University of New Haven. As with the Lawrence Tech program, faculty were placed into content cohorts, the workshop concluded with a reporting session, accountability and feedback reporting sessions were held throughout the academic year, and a final report-out of pluses and deltas concluded the program.

After many successes with course modification, the following year, 2015, the program was repeated with 28 faculty members representing 15 institutions participating. Superfluous workshop material was eliminated without a loss in learning outcomes, thus making the workshop four days instead of five. This allowed a field trip mid-week to The Henry Ford Museum and Greenfield Village with the intention that the faculty may be inspired by the innovation on display. Meanwhile University of Dayton, Western New England University, and Worcester Polytechnic Institute (WPI) had begun integration of EM in courses following the same faculty development model.

Over the following three years, KEEN grants were awarded to Lawrence Tech to organize four ICE workshops per year at various locations in the U.S. along with the year-long coaching/reporting model. Five workshop facilitators from Lawrence Tech, Univ. of New Haven, WPI, and Bucknell Univ. rotated facilitation duties and served as coaches during the academic year. The workshop material underwent further scrutiny and was ultimately pared down to 3.5 days. Long before COVID-19 made video conferencing ubiquitous, participant reporting was carried out via live video calls. Typically, two to three content cohorts were grouped for video reporting, requiring about three video calls each semester break. Two workshop facilitators were present for feedback at the video conference.

Participants received a stipend and travel reimbursement from the earliest workshops at Lawrence Tech through 2018. The stipend was paid out in increments, the first given out for completion of the workshop, the second for implementation of a course module, and the last for completion of the close-the-loop final report. Not only did this potentially aid in accountability to follow through with course modification, but it also allowed participants to end their year-long program with at least part of the stipend if they felt EM integration was "not for them."

From 2014 through 2018, about 400 faculty members participated in the national KEEN ICE program, in addition to approximately 300 more faculty members who were participating in similar ICE programs at their home institutions. Many of these faculty members integrated EM into more than one of the courses they taught. Overall, it is estimated that more than 1000 courses across about 25 academic institutions integrated EM into the content.

<u>Key Workshop Components</u>

Multiple best-practices were implemented for the workshop that led to such success:

1. Accountability through reporting

There was a high degree of accountability between the faculty members and facilitator/coaches. Initial plans for a new course module and a year-long action plan were required to be reported on the workshop's last day. Within about three months, an update was reported to the coaches via video conference, during which the finalized course module was presented. At the end of the academic year, a final report was presented on how well the module worked and what final changes would be made for the next academic year.

2. Development time and content cohorts

The workshop material was presented in a logical, sequential manner in which course learning objectives were studied first, followed by discussions of effective ACL to meet learning objectives, followed by specific ACL/PBL techniques, followed by a deep-dive into producing

effective student teams, followed by strategies to assess ACL and EM. At the conclusion of each of these topics, the participants were given time to develop their modules. The facilitators would walk throughout the room assisting. This development time is when content cohorts were crucial. During discussions (content cohorts were seated at a round table), one module idea would typically inspire others. There was also much constructive criticism as each participant would share ideas. Over 3.5 days, typically 5 hours total were allotted for development time, each ranging from ½ to 1.5 hours.

3. Playing the part of a student

The facilitation team did not simply discuss ACL techniques (including jigsaw, think-pair-share, gallery walk, rank order, design/build/test, and PBL). The participants played the role of the student to participate in actual ACLs that were used in courses by the facilitators at their home institutions. This exercise would then be followed by a debrief and reflection. By experiencing multiple live ACLs and follow-up discussions, the participants gained an appreciation for the pre-course preparation necessary, the length of class time necessary, and an idea of which techniques might work (or not work) for them. One thing to note is that, just like our students, faculty may tend to look ahead at class material. For this reason, the facilitators used a "just in time" method to release notes and handouts.

4. Templates

Two types of templates were distributed to and used by the participants. The first was a fillable template that contained all the elements of a well-structured ACL that aided in determining the time allotted for the module, team size, student deliverables, assessment technique, etc. This kept participants on-task and was a separate form of accountability. The second template was a presentation (i.e., PowerPoint) template for reporting. There was one for end-of-workshop reporting, one for mid-year reporting, and one for end-of-year reporting. These served two purposes. First, it allowed for a module summary instead of an overly detailed report. Since each presentation was of a similar format with consistent reporting criteria, assessment by facilitators and fellow participants was less taxing (i.e., no surprises or re-orientation with each report). Second, it kept each presentation in a manageable timeframe. By nature, professors are passionate about their discipline. Without a template, it is common for the professor to begin teaching the content instead of simply presenting the course changes and how the module will be implemented.

5. Chimes

With development time, breaks, meals, and timed ACL activities sprinkled throughout each day, often the noise level would be louder than expected…and of course many are not keeping track of the clock and the workshop agenda. To refocus everyone, the facilitators used a three-tone chime. These can be found on Amazon with the "Woodstock Zenergy Trio Hand Chime 7.7 inch" recommended. Voice instruction to quiet down for the next activity is surprisingly ineffective, but the chimes work nearly instantly. These are the same chimes that the facilitators use in classrooms to bring attention, and by using them in the workshop, many participants are now also using them!

6. Off-campus facilities

The first ICE workshops were hosted on college campuses to keep costs down. This method presented multiple problems. First, there will be faculty who work on that campus; the temptation is too great to step away for a meeting, or go take care of something in the office. Alternately, a colleague may seek a faculty member and ask to step away for something "*urgent."* Second, a college campus is not designed to host multi-day workshops with participants from out-of-town. The internet may be overwhelmed, the food service may not accommodate for special dietary needs, the audio/visual system may not have rapid service/support for any unforeseen issues, the lodging may be lacking amenities (like clothes hangers, or even towels), etc. After a few offerings held at college campuses, the workshops were moved to hotels. Hotel conference services are equipped to handle all these issues and more. Hotel staff (instead of the facilitators) can take care of an individual's requests/needs. And, of course, the overnight accommodations are an elevator ride away.

7. Organization

Have a clear agenda, give it to the participants, and stick to it. Organize the workshop material in a logical sequence that matches the participants' expectations and method of learning. When presenting multiple techniques (and a lot of them) over three days, give the participants a mind map that can serve as a menu of options from which to create. An example of the active learning map used is available from Gerhart [7].

8. Logistics – Organizing locations and amenities.

For the first two ICE workshops, the facilitators organized all logistics, from workshop location to lodging to meals. This took time and resources away from creating, curating, and refining workshop content. Once multiple workshops were planned per year, an administrative assistant was paid to organize all the logistics. In so doing, better monetary deals with hotels were arranged as well.

<u>Participant Feedback and Workshop Improvements</u>

Post-workshop surveys were distributed to participants, and while the results were not aggregated nor quantified, qualitatively, the responses were overwhelmingly positive. Typical comments indicated that the workshop was well-organized, the facilitators were accessible and knowledgeable, and being in the role of the student was of utmost importance. The most common criticism included wanting more workshop time for each technique and worries about how technical course content (i.e., non-EM content) may be reduced or cut to accommodate EML.

A frequently raised question during the workshop pertained to concerns about EM content cutting into other *required* course content. To address this, examples were presented throughout the workshop of how ACL and PBL (and student-centered learning in general) can increase the time for content while effectively incorporating EM experiences. ACL and PBL were chosen to incorporate EM for two important reasons: ACL and PBL align well with many EM student outcomes and allow for "*stacking*" EM with technical content.

By the conclusion of the first two years of ICE faculty development, the assumption was proven true that the process outcomes associated with student-centered learning aligned well with the

skills associated with the entrepreneurial mindset [5], [6] which included persistence, creativity, curiosity, collaboration, innovation, time management, critical thinking, global awareness, self-directed research, life-long learning, learning through failure, tolerance for ambiguity, and estimation. In addition, there was ample evidence that all of these attributes are highly coveted attributes of engineers entering the workforce [8], [9], [10], [11], [12], [13], [14]. Over the subsequent years, challenge-based learning and active/collaborative learning (ACL) have demonstrated effectiveness in emphasizing student practice of the skills associated with the entrepreneurial mindset [5], [6], [15], [16], [17], [18], [19], [20], [21], [22], [23], [24].

The technique to integrate EM into ACL and PBL has been referred to as stacking. The concept is to "sprinkle in" EM attributes with the main discipline-specific learning objectives. Details can be found from Melton in [25].

Now

In 2019, the Kern Family Foundation began administering the ICE program, ending the yearly grants given to Lawrence Tech for the administration. The idea was for KEEN to offer many more EM workshops that went beyond the ICE theme of modifying courses to incorporate EM. By centralizing the administration of all these workshops, they could be advertised and branded in a similar fashion. It also allowed the foundation to hire personnel dedicated specifically to workshop coordination and oversight. In addition, the foundation began issuing each partner institution (by then more than 40 institutions were partners) five all expenses paid "tickets" per year to send faculty members to workshops. With the growing desire of faculty to create EML, the faculty stipends were ended.

Near the beginning of 2019, it was time to scrutinize the content of ICE. Since ICE inception, the EM framework (i.e., student learning outcomes) was in flux, but by 2015, a common framework was developed and incorporated as shown in the Appendix. While many improvements were being made to each successive ICE workshop to more closely align ACL and PBL to EM (hence creating effective EML), a dedicated effort was made to focus all of the content and the participants' course modifications on incorporating the Three C's – Curiosity, Connections, Creating Value. By the conclusion of three ICE workshops in 2019, each element of the workshop included a reflection that clearly indicated how the ACL or PBL was effectively EML because of the incorporation of some of the Three C's (as well as some of the other "example behaviors"). In addition, during the participants' end-of-workshop reporting, the facilitators emphasized critiquing the strengths or shortcomings in relation to incorporation of the Three C's.

Beginning in 2019, a physical (i.e., printed) guidebook is provided to each participant. It contains descriptions of each major section of the workshop, various handouts for activities and later reference, and ample space to take notes in each section. The participants have found this resource extremely valuable post-workshop as a dedicated reminder of techniques, ideas, and future plans.

Since all the content generated by faculty at a workshop is understood to be shared to the network, one of the more difficult aspects of pre-2019 workshops was archiving and

disseminating the course modules produced by the participants. The Kern Family Foundation (KFF) was storing some of the module material, and some faculty even published conference papers. As one would imagine, sorting and finding the material was difficult. Thus, KFF developed an online social platform and sharing resource known as Engineering Unleashed (www.engineeringunleashed.com). Any faculty member or instructor can register to be part of the Engineering Unleashed community, not just KEEN partner institution faculty. Within Engineering Unleashed, an instructor can create a "card" that describes and includes resources (including documents, videos, graphics, etc.) for curricular or co-curricular EM activities. The database of cards is searchable. At the conclusion of the year-long faculty development program, faculty are expected to produce a card and publish it. During the year, the card is placed in draft where only the creator and coaches can view it. During coaching and trial of the course module, the card is refined until it is suitable for public consumption.

One final major change occurring in 2019 was the incorporation of an online course management platform. Much like Blackboard® or Canvas® is used for course management at many college campuses, the KEEN workshops use Thinkific®, which is linked to, and accessed through, the Engineering Unleashed site. Referred to as *Meetup*, during the workshop, it is not only a place to share learning resources, but it also allows for a linear or incremental learning process during the workshop, as the facilitators open new modules with a "*just-in-time*" learning structure. In addition, a *Quick Start* series of learning modules is presented to the participants before arriving at the workshop that includes foundational information and definitions used though the workshop. The participants can work through the *Quick Start* modules at a time of their choosing before arriving for the workshop. After the workshop, a *Press Onward* series of learning modules assists with coaching and implementation.

With the success of ICE, more EM-themed workshops were developed by KEEN. They include storytelling, maker-space incorporation, making academic change, incorporation of EM into research, diversity & inclusion, and more. These are all part of what is known as Engineering Unleashed Faculty Development. Many of them incorporate major elements used for ICE, including year-long coaching, in-workshop development time, incremental reporting, and card publication. Also in 2021, the ICE facilitators developed a new workshop known as ICE 2.0. For many years, the facilitators have been informally training and equipping institutions to run their own in-house faculty development programs, but ICE 2.0 is a specific training program for such. It uses the ICE model to "train the trainers."

Due to COVID-19, the ICE workshop had to pivot and develop an online workshop (just like many of our other educational endeavors at that time). While it is very much like in-person ICE workshops, the facilitators discovered a few best practices unique to online faculty development. 1) The synchronous sections are kept to two hours or less with ample breaks in between. 2) The facilitators assign a "tech" person to work behind the scenes of the main activity to monitor the chat, set-up breakout rooms, etc. 3) A package is mailed to the participants a couple of weeks before the workshop. It contains an introduction letter, some handouts intended for handwritten activities, the field guide, "tools" to use for hands-on activities (such as Play-Doh, a Slinky, a small ruler), KEEN swag, snacks and tea, and a gift card for one or more of the lunch breaks. This package has helped to build community, which in person would normally take place during meals and breaks. 4) The facilitators and coaches host online networking and office hours before

and after the workshop content each day. Some participants just enjoy casual social time with colleagues and new friends, whereas others have questions for the trainers. Breakout rooms can accommodate multiple inquiries simultaneously.

One online ICE workshop is still offered each year. This is intended to accommodate those who cannot travel or have time restrictions due to personal or work constraints.

Conclusions

With the use of best practices, continual improvements, and success in the wide-spread of EML, ICE has garnered many accolades; many other faculty development programs have replicated the program. At time of publishing, there have been 36 KEEN ICE workshops (not including those held for specific institutions) and over 1000 faculty trained. In addition, a high but untracked number of ICE-like workshops and trainings have been hosted at a multitude of college campuses. The core facilitation team has grown and continues to do so with increasing demand. In 2024, there will be five official ICE workshop offerings. The authors are in awe at what has been accomplished and hope this historical compilation will anchor future conversations of faculty development workshops.

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References

[1] Kern Entrepreneurial Engineering Network, https://engineeringunleashed.com/about. [Accessed Jan. 29, 2023].

[2] R. M. Felder and R. Brent, "The National Effective Teaching Institute: Assessment of Impact and Implications for Faculty Development," *J. Eng. Educ.*, vol. 99, no. 2, pp. 121–134, 2010, doi: 10.1002/j.2168-9830.2010.tb01049.x.

[3] A. F. Mckenna, A. M. Johnson, B. Yoder, R. C. Chavela Guerra, and R. Pimmel, "Evaluating Virtual Communities of Practice for Faculty Development," *J. Fac. Dev.*, vol. 30, no. 1, pp. 31–40, Jan. 2016.

[4] G. Light, S. Calkins, M. Luna, and D. Drane, "Assessing the Impact of a Year-Long Faculty Development Program on Faculty Approaches to Teaching," *Int. J. Teach. Learn. High. Educ.*, vol. 20, no. 2, pp. 168–181, 2009.

[5] D. Carpenter, K. Hayes, C. Ward, and A. Gerhart, "Assessment and Evaluation of a Comprehensive Course Modification Process," *The Journal of Engineering Entrepreneurship*, vol. 2, no. 2, 2011.

[6] A.L. Gerhart and D.D. Carpenter, "Campus-wide Course Modification Program to Implement Active & Collaborative Learning and Problem-based Learning to Address the Entrepreneurial Mindset," *Proceedings of the 2013 ASEE Annual Conference & Exposition*, Atlanta, GA, June 2013.

[7] A.L. Gerhart, "A Mind Map for Active Learning Techniques," *Proceedings of the 2023 ASEE Annual Conference & Exposition*, 2023.

[8] D. Berrett, "Creativity: a Cure for the Common Curriculum," *The Chronicle of Higher Education*, April 1, 2013. http://chronicle.com/article/The-Creativity-Cure/138203/?cid=at&utm_source=at&utm_medium=en. [Accessed January 31, 2024].

[9] "How should colleges prepare students to succeed in today's global economy - Based On Surveys Among Employers And Recent College Graduates Conducted On Behalf Of: The Association Of American Colleges And Universities," Peter D. Hart Research Associates, Inc., 2006. https://www.sg.inter.edu/wp-content/uploads/Documentos/asuntos_academicos/PEG/How_Should_Colleges_Prepare_Students_To_Succeed_in_Todays_Global_Economy_AACU_2006.pdf [Accessed January 31, 2024 2014].

[10] American Society for Training and Development and U.S. Department of Labor, *Workplace basics: The skills employers want*, 1988.

[11] Quality Assurance in Undergraduate Education, Wingspread Conference, ECS, Boulder, CO, 1994.

[12] K. Fischer, "A College Degree Sorts Job Applicants, but Employers Wish It Meant More," *The Chronicle of Higher Education*, March 4, 2013. http://chronicle.com/article/The-Employment-Mismatch/137625. [Accessed January 31, 2024].

[13] Maguire Associates, Inc. in association with *The Chronicle of Higher Education* and American Public Media's *Marketplace*, December 2012. http://chronicle.com/items/biz/pdf/Employers%20Survey.pdf. [Accessed April 12, 2014].

[14] Maguire Associates, Inc. in association with *The Chronicle of Higher Education* and American Public Media's *Marketplace*, December 2012. http://chronicle.com/items/biz/pdf/Employers%20Survey%20-Annotated%20Instrument.pdf. [Accessed April 12, 2014].

[15] A.L. Gerhart and D.E. Melton, "Entrepreneurially Minded Learning: Incorporating Stakeholders, Discovery, Opportunity Identification, and Value Creation into Problem-based Learning Modules with Examples and Assessment Specific to Fluid Mechanics," *The Journal of Engineering Entrepreneurship*, Vol. 8, No. 1, 2017.

[16] A.L. Gerhart and D.E. Melton, "Entrepreneurially Minded Learning: Incorporating Stakeholders, Discovery, Opportunity Identification, and Value Creation into Problem-based Learning Modules with Examples and Assessment Specific to Fluid Mechanics," *Proceedings of the 2016 ASEE Annual Conference & Exposition*, New Orleans, LA, June 2016.

[17] L. Liu, J. Mynderse, A. Gerhart, and S. Arslan, "Fostering the Entrepreneurial Mindset in the Junior and Senior Mechanical Engineering Curriculum with a Multi-Course Problem-based Learning Experience," *Proceedings of the 45th ASEE/IEEE Frontiers in Education Conference*, El Paso, TX, October 2015.

[18] A.L. Gerhart, D.D. Carpenter, and R.W. Fletcher, "Developing Design and Professional Skills through Project-based Learning focused on the Grand Challenges for Engineering," *Proceedings of the International Symposium on Project Approaches in Engineering Education, International Joint Conference on the Learner in Engineering Education*, San Sebastian, Spain, July 7, 2015.

[19] A.L. Gerhart, D.D. Carpenter, "Jigsaw, Gallery Walk, and Controversy – Combining Three Active Learning Techniques to Promote Self-Directed Learning," *Proceedings of Active Learning in Engineering Education, International Joint Conference on the Learner in Engineering Education*, San Sebastian, Spain, July 6, 2015.

[20] J. Mynderse, A. Gerhart, L. Liu, and S. Arslan, "Multi-Course Problem-based Learning Module spanning across the Junior and Senior Mechanical Engineering Curriculum: Mechatronics, Fluid Mechanics, and Heat Transfer," *Proceedings of the 2015 ASEE Annual Conference & Exposition*, Seattle, WA, June 2015.

[21] A.L. Gerhart, D.D. Carpenter, R.W. Fletcher, and E. Meyer, "Combining Discipline-specific Introduction to Engineering Courses into a Single Multi-discipline Course to Foster the Entrepreneurial Mindset with Entrepreneurially Minded Learning," *Proceedings of the 2014 ASEE Annual Conference & Exposition*, Indianapolis, IN, June 2014.

[22] S.D. Schneider, A.L. Gerhart, and D.D. Carpenter, "Active classroom of students – check! Engaged faculty – check! A development model – check!" *Proceedings of the Network for Academic Renew Conference – Diversity, Learning, and Student Success: Policy, Practice, Privilege; Association of American Colleges and Universities*, Chicago, March 27-29, 2014.

[23] A.L. Gerhart, R.W. Fletcher, and D.D. Carpenter, "Effectively Communicating Between the Engineer and Customer," *Active Learning in Engineering Education Conference*, Caxias do Sul, Brazil, January 20-22, 2014.

[24] A.L. Gerhart and R.W. Fletcher, “Project-Based Learning and Design Experiences in Introduction to Engineering Courses – Assessing an Incremental Introduction of Engineering Skills,” *Proceedings of the 2011 ASEE Annual Conference & Exposition*, Vancouver, BC, June 2011.

[25] D.E. Melton, “Stacking Entrepreneurially Minded Learning Alongside Other Pedagogies,” *KEEN’zine – Intrapreneurship Edition*, 2015. https://engineeringunleashed.com/keenzine3/. [Accessed January 30, 2024.]

Appendix


KEEN
STUDENT OUTCOMES
EXAMPLE
BEHAVIORS
ENTREPRENEURIAL MINDSET
CURIOSITY
DEMONSTRATE constant curiosity about our changing world
EXPLORE a contrarian view of accepted solutions
CONNECTIONS
INTEGRATE information from many sources to gain insight
ASSESS and MANAGE risk
CREATING VALUE
IDENTIFY unexpected opportunities to create extraordinary value
PERSIST through and learn from failure
COUPLED WITH
ENGINEERING THOUGHT AND ACTION
APPLY creative thinking to ambiguous problems
APPLY systems thinking to complex problems
EVALUATE technical feasibility and economic drivers
EXAMINE societal and individual needs
EXPRESSED THROUGH
COLLABORATION
FORM and WORK in teams
UNDERSTAND the motivations and perspectives of others
AND
COMMUNICATION
CONVEY engineering solutions in economic terms
SUBSTANTIATE claims with data and facts
AND FOUNDED ON
CHARACTER
IDENTIFY personal passions and a plan for professional development
FULFILL commitments in a timely manner
DISCERN and PURSUE ethical practices
CONTRIBUTE to society as an active citizen

KEEN

ENGINEERING UNLEASHED

COMPLEMENTARY SKILLS

OPPORTUNITY	DESIGN	IMPACT
Identify an opportunity	**Determine** design requirements	**Communicate** an engineering solution in economic terms
Investigate the market	**Perform** technical design	**Communicate** an engineering solution in terms of societal benefits
Create a preliminary business model	**Analyze** solutions	**Validate** market interest
Evaluate technical feasibility customer value societal benefits economic viability	**Develop** new technologies (optional)	**Develop** partnerships and build a team
Test concepts quickly via customer engagement	**Create** a model or prototype	**Identify** supply chains distribution methods
Assess policy and regulatory issues	**Validate** functions	**Protect** intellectual property

THESE SPECIFIC SKILLS REINFORCE THE DEVELOPMENT OF AN ENTREPRENEURIAL MINDSET