Advances in Engineering Education

FALL 2018

Developing an Entrepreneurial Mindset in Engineering Students Using Integrated E-Learning Modules

RONALD S. HARICHANDRAN

NADIYE O. ERDIL

MARIA-ISABEL CARNASCIALI

JEAN NOCITO-GOBEL

AND

CHERYL LI
University of New Haven
West Haven, CT

ABSTRACT

An innovative approach to develop an entrepreneurial mindset in all undergraduate engineering and computer science students is being developed and implemented. The approach consists of the development of short e-learning modules on 18 entrepreneurial topics and the integration of these modules into regular courses in programs. A flipped classroom model is used along with contextual activities related to course content, in which students apply what they learned through the modules. The methodology addresses the credit constraints in engineering and computer science programs, the lack of instructor expertise in entrepreneurial topics, and constraints in classroom instruction time. Through a mini-grant program, six modules were deployed by 29 faculty at 24 institutions nationwide from spring 2016 to spring 2017, and 30 faculty, some from previous institutions, and others from an additional 18 institutions, deployed modules in 2017-18. Preliminary assessment of the effectiveness of the approach in developing an entrepreneurial mindset in students is presented.

Key words: Entrepreneurship, E-learning, Flipped Classroom

MOTIVATION

Many engineering colleges are currently attempting to impart entrepreneurial skills to their students (Kuratko, 2005; Kauffman Foundation, 2008; Duval-Couetil, 2013). A variety of approaches are being used, including: having students take business-oriented courses; encouraging students to participate in extracurricular activities, such as startup or innovation competitions; working with startup companies in businesses incubators (Archibald et al., 2005; Ochs et al., 2006; Echempati, 2011; Reimer et al., 2011; Mallory, 2015; Jayaraman & Swartwout, 2015; Gandhi et al., 2016). A significant constraint within engineering programs is an already packed curriculum and limited elective credits that can be applied toward courses in business/entrepreneurship. Having to know the value of entrepreneurship in advance and take additional credits beyond program requirements limits the number of students who take entrepreneurship courses. From the faculty perspective, small colleges are particularly challenged by not having enough faculty with expertise in entrepreneurship. To overcome these constraints and difficulties, we created a model that enables all engineering and computer science students to develop an entrepreneurial mindset without having to take extra courses. The model is transferable to other institutions and scalable to accommodate large numbers of students.

INTEGRATED E-LEARNING MODULES

The approach we are using consists of the integration of 18, short, e-learning modules on a variety of topics related to entrepreneurial thinking into regular courses that students take over four years of engineering and computer science programs. The 18 modules are designed to address entrepreneurially-minded learning (EML) outcomes and complementary skills (KEEN, 2016; Rae & Melton, 2016; London et al., in press). Fourteen of these modules have been developed, and the remaining four will be developed by fall 2018. At its core, EML is a pedagogical strategy that encourages students to possess *curiosity* to investigate a rapidly changing world, to innovate by making *connections* between different streams of information, and to *create value* for others. EML in engineering education is more than stimulating entrepreneurship, which focuses on venture creation. EML outcomes and the complementary skills addressed in this study allow graduates to be innovative, seize opportunities, and apply their technical skills to produce solutions that have societal as well as economic impact.

We selected content experts from academia and industry to develop the modules through a request for proposals (RFPs) issued prior to each development cycle. The RFPs were distributed by e-mail to faculty at member institutions of the Kern Entrepreneurial Engineering Network (KEEN), engineering deans at numerous colleges and universities (asking them to forward to their faculty), and working professionals known to us. A payment of $3000 was offered to develop each module. Together with a program manager from the Kern Family Foundation, the agency funding our work, we selected one or a group of content experts to develop each module. Selected content experts worked with an e-learning course designer we provided. We also assembled review teams to guide the development of each module. Each module consists of text, short videos, interactive exercises, quizzes and a final comprehensive test. The modules were developed within the Blackboard Learning Management System (LMS). Each development cycle lasted about 4 months and 3-4 modules were developed during each cycle. Harichandran et al. (2015) and Erdil et al. (2016) provide an overview of some modules.

Each of the modules has associated learning outcomes. Modules were integrated into specific engineering and computer science courses at the University of New Haven in the academic year following development. Before the beginning of each semester, we helped instructors develop a contextual project or assignment related to the modules to be integrated into their courses. This reinforcing activity was designed so that students applied what they learned in the modules to course content. Instructors used a flipped classroom model in which students were asked to complete the modules outside of class time during a two-week period and instructors engaged students through in-class or online discussions related to the modules. Each module takes 4-7 hours to complete. Students must score at least 80% on the final quiz to pass a module and are given three attempts to achieve this score during the two-week period. In addition to assessing student participation in discussions and performance in the contextual assignment, instructors were encouraged to include questions related to the modules on course examinations. Instructors assign part of the course grade to passing the module and for student performance in the contextual activity. The e-learning module integration process is shown in Figure 1, including the two weeks allocated for students to complete the module, as well as the periods for discussion, the contextual project and assessment.

Our approach has the following advantages:

1. Students can learn entrepreneurial topics without taking extra courses or credits.
2. Faculty do not need to be experts in the entrepreneurial topics. They only need to be familiar with the content and develop a contextual activity, in which students apply what they learn.
3. The contextual activity can be aligned with the regular content of the course, and therefore students learn to apply entrepreneurial concepts to solve problems related to the course.
4. Faculty do not need to give up class time dedicated to teaching technical topics, since students learn the entrepreneurial topics outside of class.

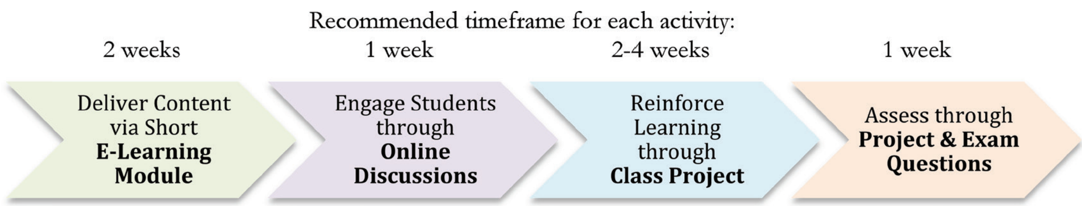

Figure 1. The process of integrating an e-learning module into a course.

5. The entrepreneurial concepts delivered to students in different sections of a course are identical and is not instructor dependent.
6. By integrating the modules into regular courses, an entrepreneurial mindset can be developed in every student over the duration of his or her undergraduate program.

Students must do extra work to complete the e-learning module. However, 4–7 hours of additional work can be easily absorbed within a course spanning a semester. The additional knowledge learned and mindset developed will give students a distinct advantage in today's work environment.

DEPLOYMENT AT THE UNIVERSITY OF NEW HAVEN

We identified faculty who were interested in piloting an e-learning module in their classes in spring 2015. Each faculty developed a contextual activity for his or her class that would reinforce the e-learning module content, typically by revising existing projects/activities, or in some cases, developing new projects or components. The four courses in which modules were piloted are listed in Table 1. Instructors provided feedback at the end of the semester summarizing their contextual activity and assessment, and whether the module enhanced student learning in the context of their course, along with challenges faced and suggested changes for the future.

Prior to broad deployment of the e-learning modules in fall 2015, faculty involved in the deployment participated in a two-hour training session in late August. During the training, faculty attended breakout sessions to discuss specific details of the deployment in their class, including the timeline, contextual activity, assessment activities, completion of feedback forms, and logistics/technical issues. Lessons learned from piloting the four modules in the spring were shared.

Broad deployment of the modules occurred in multiple sections of targeted courses beginning in fall 2015 (see Table 2). Details and results of the deployment are discussed by Erdil et al. (2016). Ten

Table 1. Pilot Deployment at the University of New Haven in Spring 2015.

Module	Course	Level
Developing Customer Awareness & Quickly Testing Concepts through Customer Engagement	Introduction to Engineering	Freshmen
Learning from Failure	Project Planning & Development	Freshmen
Establishing the Cost of Production or Delivery of a Service Including Scaling Strategies	Project Management & Engineering Economics	Sophomore
Building, Sustaining and Leading Effective Teams and Establishing Performance Goals	Mechanics & Structures Lab	Junior

Table 2. Deployment at the University of New Haven from Fall 2015 to Spring 2017.

Module	Course	# Sections / # Students	Semester
Developing Customer Awareness & Quickly Testing Concepts through Customer Engagement	Introduction to Engineering	7 / 120 4 / 69 7 / 114 3 / 54	Fall 2015 Spring 2016 Fall 2016 Spring 2017
Learning from Failure	Project Planning & Development	7 / 150 2 / 49 7 / 123 2 / 33	Fall 2015 Spring 2016 Fall 2016 Spring 2017
Establishing the Cost of Production or Delivery of a Service Including Scaling Strategies	Project Management & Engineering Economics	3 / 66 5 / 87 3 / 50 4 / 81	Fall 2015 Spring 2016 Fall 2016 Spring 2017
Building, Sustaining and Leading Effective Teams and Establishing Performance Goals	Chemical Engineering Lab Mechanical Engineering Lab Mechanical Engineering Lab Electrical Engineering Lab Mechanics & Structures Lab System Engineering Lab	1 / 13 1 / 10 2 / 30 1 / 23 1 / 15 1 / 12	Fall 2015 Spring 2017
Applying Systems Thinking to Complex Problems	Senior Design I (MECH, ELEC, CHME and CIVL) Steel & Concrete Design Senior Design I (Interdisciplinary)	5 / 97 1 / 16 3 / 57	Fall 2015 Fall 2016 Fall 2016
Thinking Creatively to Drive Innovation	Materials in Engineering Systems	1 / 20 1 / 19	Fall 2016 Spring 2017
The Elevator Pitch: Advocating for Your Good Ideas	Senior Design II (MECH, ELEC, CHME, CIVL, SYST, CS)	8 / 114	Spring 2017
Adapting a Business to a Changing Climate Role of Product in Value Creation Developing a Business Plan that Addresses Stakeholder Interests, Market Potential and Economics	Business and Entrepreneurship for Engineers and Scientists	1 / 15	Spring 2017

different modules have been integrated into 15 courses, including 3 disciplinary laboratory courses, 6 disciplinary senior design courses, and 3 modules integrated into a new course entitled *Business and Entrepreneurship for Engineers and Scientists* offered during spring 2017.

EXAMPLE OF MODULE INTEGRATION[1]

The *Learning from Failure* module was integrated into EASC 1109: *Project Planning and Development*. The following two new course learning outcomes were added to reflect the module's content: (1) Develop

[1]Harichandran et al. (2015) and Erdil et al. (2016) provide descriptions of additional modules. Click here for additional examples of module integration.

a list of practical options to correct or avoid potential mistakes that may occur in specific projects; and (2) Explain the potential risks of failure and propose solutions in terms familiar to various stakeholders.

Students complete the module during weeks 7 and 8 of the 15-week semester. During week 9, the instructor engages the students in an online discussion around the following tasks: (1) Find and research a company/product on the brink of failure; and (2) Take the reins of the company/product and recommend a turnaround strategy. Each student is expected to contribute to the discussion and respond to posts by at least two other students.

Students engage in a manufacturing and robotics project during weeks 9–11, which constitutes the contextual activity. The project is complex enough that failure is almost inevitable. In their final report, each team is asked to include the following two items related to the e-learning module:

1. From the lessons learned in the *Learning from Failure* e-learning module, list what could have been done differently to avoid the mistakes that occurred while implementing this project.
2. Discuss what potential risks of failure exist for a project like this if done in industry, and propose solutions to alleviate these risks in terms familiar to various stakeholders.

The depth of coverage related to EML outcomes and complementary skills provided by the e-learning module and contextual activity are shown in Table 3. Empty cells indicate that the module does not address the corresponding outcomes/skills.

Starting in fall 2017 each instructor will use the rubric shown in Appendix-Figure A-1 to rate each team's report on a 5-point scale related to the assessment outcomes shown in the figure. Assessment outcomes are a subset of the learning outcomes.

DEPLOYMENT AT OTHER UNIVERSITIES AND COLLEGES

In spring 2016, we initiated a pilot mini-grant program targeted at partner KEEN institutions to externally deploy the e-learning modules. Six faculty were selected from five institutions (see Appendix Table A-1) through an RFP issued in October 2015. We held a virtual workshop to help instructors with deployment and development of contextual activities. An IT staff member at the University of New Haven worked with an IT staff member at each deploying institution to transfer module content from Blackboard to the LMS at that institution. The deployment included pre- and post-surveys for each module. At the end of the semester we collected these surveys, feedback from faculty, course syllabi and the description of the contextual activities. The pilot provided insight and resources that helped us streamline the deployment process and improve the surveys.

Following the successful pilot deployment, we initiated a large-scale mini-grant program to broaden deployment and include institutions outside KEEN. We issued an RFP in April 2016 by

Table 3. Depth of Coverage Related to EML Outcomes and Complementary Skills Provided by Learning from Failure Module.

EML Outcomes

Dimension	Target	Depth
CURIOSITY	Demonstrate constant curiosity about our changing world	Low
	Explore a contrarian view of accepted solutions	High
CONNECTIONS	Integrate information from many sources to gain insight	Medium
	Assess and manage risk	High
CREATING VALUE	Identify unexpected opportunities to create extraordinary value	Low
	Persist through and learn from failure	High

EML Complementary Skills

Dimension	Target	Depth
OPPORTUNTIY	Identify an opportunity	
	Investigate the market	
	Create a preliminary business model	
	Evaluate technical feasibility, customer value, societal benefits, economic viability	High
	Test concepts quickly via customer engagement	Low
	Assess policy and regulatory issues	
IMPACT	Communicate an engineering solution in economic terms	Medium
	Communicate an engineering solution in terms of societal benefits	Medium
	Validate market interest	
	Develop partnerships and build a team	High
	Identify supply chains distribution methods	
	Protect intellectual property	

e-mail to faculty at KEEN institutions, and engineering deans at numerous colleges and universities (asking them to forward to their faculty), and selected faculty from 22 institutions around the U.S. to deploy e-learning modules (see Appendix Table A-2). All the faculty participated in a half-day training program we conducted prior to the 2016 ASEE Annual Conference that focused on KEEN goals and objectives, strategies for deployment, development of contextual activities, and logistics for content transfer. We generated common course cartridges for each module to transfer content from Blackboard into various LMS's such as Blackboard, Canvas, Desire2Learn, Sakai, iLearn, and Moodle.

During the 2017-18 academic year, 30 faculty, 18 of them from institutions that did not participate previously, are deploying the e-learning modules (see Appendix Table A-3). The complex logistics required to administer the module development and large-scale deployment are described at www.newhaven.edu/KEEN/aee-paper-appendix/.

INDIRECT ASSESSMENT

We conducted assessment on the acquisition of knowledge from the e-learning modules and on the perceived benefits gained by integrating them into engineering and computer science classes. We used module-specific pre- and post-surveys to assess students' knowledge acquisition. The surveys include 6-8 items focusing on each module. The results from the 16 external deployments of six modules in fall 2016 indicated that students gained knowledge from five modules, with the exception of the Effective Teams module, which was deployed only at one institution (see Figure 2). We also administered forms to obtain feedback from students and instructors to assess the perceived benefits of the modules. Figures 3 and 5 show the average ratings, on a 5-point scale, by faculty and students, respectively, across all institutional offerings of each module for the four statements shown on the right of each figure, in a stacked bar graph format. In general, faculty felt that the modules provided useful material, enhanced student learning, triggered student curiosity, enriched course content, and helped expand the boundaries of traditional classroom based learning (Figures 3 and 4). While student perceptions were not as positive as those of the faculty, they nevertheless appreciated the value of the modules and of the associated contextual activities (Figure 5).

Overall, the assessment results suggest that students generally acquired knowledge through the integrated e-learning modules. An interesting outcome is that faculty rated the value of the e-learning modules higher than students did. Furthermore, faculty willingness to integrate e-learning modules into more classes was significantly higher than students' willingness to take more classes with e-learning modules. Students' reluctance to take more classes with e-learning modules is most likely because they do not want to do extra work.

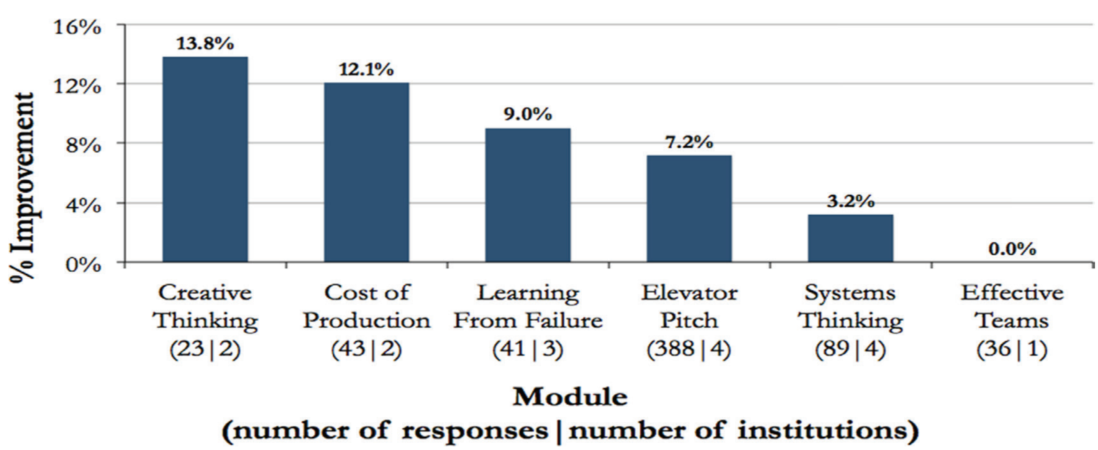

Figure 2. Average improvement of knowledge after integrating e-learning modules.

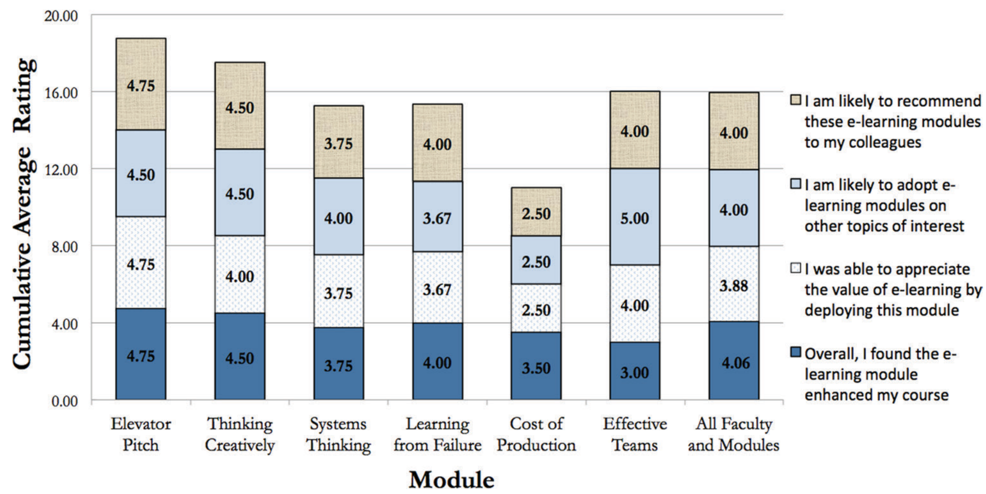

Figure 3. Faculty user experience.

We also developed and validated a new survey instrument to measure the entrepreneurial mindset of students. We are assessing the effectiveness of integrating e-learning modules into regular courses within programs by administering this instrument to students when they are incoming freshmen and again when they are seniors. The instrument consists of 50 questions loaded on 14 factors that are associated with the EML learning outcomes discussed above and is an expanded version of a 37-question instrument (Li et al, 2016). The first set of data from this survey instrument is being analyzed.

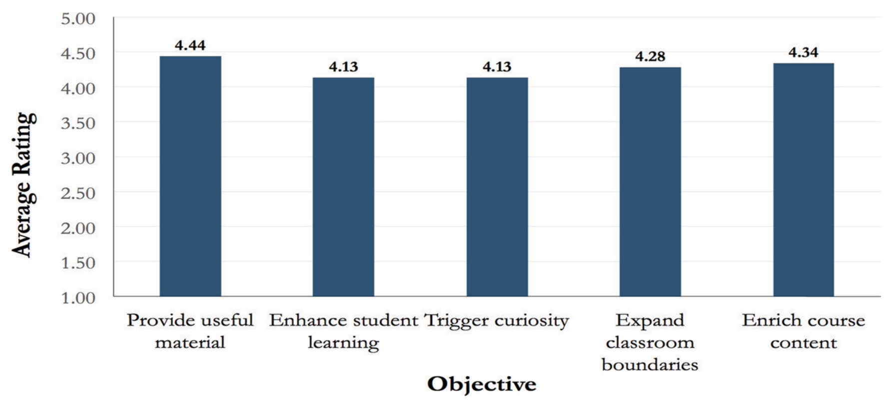

Figure 4. Faculty rating of the benefits of the e-learning modules.

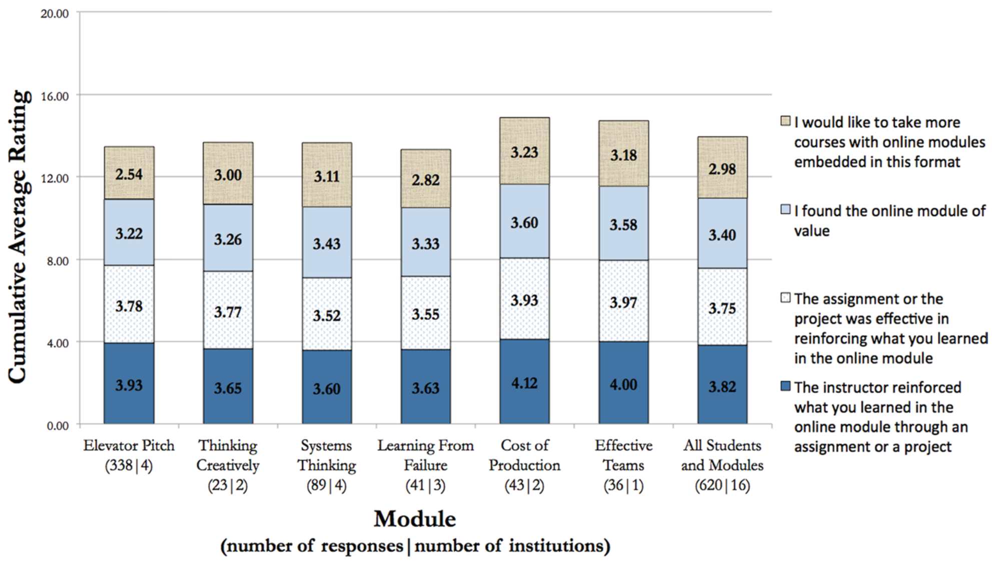

Figure 5. Student user experience.

DIRECT ASSESSMENT

We are using the assessment results to improve the content and integration of the e-learning modules and further refine the assessment processes. Starting in fall 2017, we are implementing direct assessment of student learning. Assessment outcomes for each module were identified from the learning outcomes, and faculty are using rubrics to assess how well students do in the contextual activities. Data from this direct assessment are expected to shed further light on student learning through the integrated e-learning modules.

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

An innovative approach of integrating short e-learning modules on entrepreneurial topics into regular engineering and computer science courses is being used at the University of New Haven with the goal of developing an entrepreneurial mindset in students. A large-scale national mini-grant program was launched and faculty at 42 other institutions deployed modules in their courses since spring 2016.

Indirect assessments revealed that both faculty and students found the integrated modules approach to be quite effective and valuable in learning entrepreneurial concepts. Faculty were more enthusiastic about deploying multiple modules in courses than students were about taking them. While module-specific pre- and post-surveys showed modest improvement in knowledge gained by students, we are strengthening assessment by implementing direct assessment of student learning. Furthermore, we are assessing the effectiveness of using integrated e-learning modules across all four years of undergraduate programs by using an entrepreneurial mindset assessment instrument.

ACKNOWLEDGMENTS

The work reported herein was funded by the Kern Family Foundation. Ms. Karen Wilken and Dr. Doug Melton, program managers at the foundation, provided valuable feedback during the development of the e-learning modules. Ms. Meghan Baggili provided support in administering the mini-grant program.

REFERENCES

Archibald, M., Clauss, M., & Dupree, J., (2005). Entrepreneurship in capstone design using interdisciplinary teams and a business plan competition. *Proceedings, ASEE Annual Conference*, Portland, OR. https://peer.asee.org/15567

Brouwer, R., Sykes, A., & VanderLeest, S. (2011) Entrepreneurial mindset development in a senior design/ capstone course. *Proceedings, ASEE Annual Conference*, Vancouver, BC, Canada, Paper AC 2011–2462, 7 pp. https://peer.asee.org/17913

Duval-Couetil, N. (2013). Assessing the impact of entrepreneurship education programs: Challenges and approaches. *Journal of Small Business Management*, 51(3): 329–351.

Echempati, R. (2011). Integration of innovation and entrepreneurship topics into the design courses experience and lessons learned. *Proceedings, ASEE Annual Conference*, Vancouver, BC, Canada, Paper AC 2011–849, 13 pp. https://peer.asee.org/18263

Erdil, N. O., Harichandran, R. S., Carnasciali, M-I., Nocito-Gobel, J., & Li, C. (2016). Integrating e-learning modules into engineering courses to develop an entrepreneurial mindset in students. *Proceedings, ASEE Annual Conference*, New Orleans, LA, Paper 14885, 16 pp.

Gandhi, S., J., Beruvidas, M. G., Taghazadeh, S., & Cross, J. A. (2016). A comprehensive review of entrepreneurship course offering in engineering programs. *Proceedings, ASEE Annual Conference*, New Orleans, LA, Paper 16248, 12 pp. https://peer.asee.org/26295

Harichandran, R. S., Carnasciali, M-I., Erdil, N., Li, C., Nocito-Gobel, J., & Daniels, S., (2015). Developing entrepreneurial thinking in engineering students by utilizing integrated online modules. *Proceedings, ASEE Annual Conference*, Seattle, WA, Paper 11487, 21 pp.

Jayaram, S., & Swartwout, M. A. (2015). Systems engineering entrepreneurship modules across aerospace engineering curriculum. *Proceedings, ASEE Annual Conference*, Seattle, WA, Paper 12760, 10 pp. https://peer.asee.org/24791

Kauffman Foundation (2008). Entrepreneurship in American higher education: A Report from the Kauffman Panel on Entrepreneurship Curriculum in Higher Education. https://www.kauffman.org/-/media/kauffman_org/research-reports-and-covers/2008/07/entrep_high_ed_report.pdf

Kern Entrepreneurial Education Network (KEEN) (2016). Mindset + skillset: Education in tandem. Retrieved from https://engineeringunleashed.com/Mindset-Matters/Framework.aspx

Kuratko, D.F. (2005). The emergence of entrepreneurship education: Development, trends, and challenges. *Entrepreneurship: Theory and Practice*, 29(5): 577–597.

Li, C., Harichandran, R. S., Carnasciali, M-I., Erdil, N. O., & Nocito-Gobel, J. (2016). Development of an instrument to measure the entrepreneurial mindset of engineering students. *Proceedings, ASEE Annual Conference*, New Orleans, LA, Paper 15139, 15 pp.

London, J. S., Bekki, J. M., Brunhaver, S. R., Carberry, A. R., & McKenna, A. F. (accepted). A framework for entrepreneurial mindsets and behaviors in undergraduate engineering students, *Advances in Engineering Education*.

Mallory, J. A. (2015). A module to introduce the entrepreneurial mindset into thermodynamics – a core mechanical engineering course. *Proceedings, ASEE Annual Conference*, Seattle, WA, Paper 12425, 11 pp.

Ochs, J., Lennon, G., Watkins, T., & Mitchell, G., (2006). "A comprehensive model for integrating entrepreneurship education and capstone projects while exceeding ABET requirements." *Proceedings, ASEE Annual* Conference, Chicago, IL, https://peer.asee.org/778

Rae, D., & Melton, D. E. (2016). Developing an entrepreneurial mindset in US engineering education: An international view of the KEEN project. *Journal of Engineering Entrepreneurship*, 7(3), 1–16.

Reimer, D. M., Ahad, A., & Abro, S. R. (2011). Relationship between student competitive activities and the entrepreneurial mindset. *Proceedings, ASEE Annual Conference*, Vancouver, BC, Canada, Paper AC 2011–19, 12 pp. https://peer.asee.org/18666

AUTHORS

Ronald R. Harichandran is Dean of the Tagliatela College of Engineering at the University of New Haven. He received his BS from the University of Canterbury, New Zealand, and his MS and PhD from MIT, all in civil engineering. His research interests are in engineering education, and earthquake, pavement, bridge and fire engineering. Ron has taught a broad range of courses in structural analysis, design, dynamics, and probabilistic methods. In recognition of his leadership, research, teaching, and professional service, he was elected a Fellow of the American Society of Civil Engineers and inducted into the Connecticut Academy of Science and Engineering. At the University of New Haven, he has led two curricular innovations to integrate technical communication and entrepreneurial topics into all engineering and computer science programs.

Nadiye O. Erdil is Assistant Professor of Industrial and Systems Engineering at the University of New Haven. She was a process engineer in the sheet metal manufacturing and pipe fabrication industry for five years. She earned her BS in Computer Engineering, from Bogazici University, Turkey, and an MS and PhD in Industrial/Systems Engineering from Binghamton University. Nadiye's research interests are in quality and productivity improvement using statistical tools and lean methods, and use of information technology in operations management focusing on manufacturing and healthcare delivery operations. Her scholarly interests also include engineering education focusing on student motivation and its impact on learning, and the development of technical communication and entrepreneurial skills in engineering students. Her teaching interests are in quality management, experimental design, and engineering statistics.

Maria-Isabel Carnasciali is Associate Professor of Mechanical Engineering at the University of New Haven. She holds a BS in Engineering from MIT, and a PhD from Georgia Tech in Mechanical Engineering. Her research focuses on the nontraditional engineering student — understanding their motivations, identity development, and impact of prior engineering-related experiences. Maria-Isabel's other research interests involve validation of CFD models for aerospace applications as well as optimizing efficiency of thermal-fluid systems. She teaches thermo-fluid science courses and Introduction to Engineering, and guides several co-curricular activities. Her broad contributions have been recognized by multiple university awards including the William L. Bucknall Excellence in Teaching Award, an Excellence in Research/Creative Activity Award, and an Excellence in Faculty Mentored Undergraduate Research Award.

Jean Nocito-Gobel is Professor of Civil and Environmental Engineering at the University of New Haven. She holds a BS in Civil Engineering from Manhattan College, MS in Civil Engineering from the Ohio State University, and PhD in Environmental Engineering from the University of Massachusetts, Amherst. Her scholarly interests include modeling the transport and fate of contaminants in groundwater and surface water systems, as well as engineering education reform. Jean has been engaged in educational initiatives including the integration of technical communication and entrepreneurial topics in engineering curricula, and is coordinator for the first-year Intro to Engineering course. She received the 2017 Excellence in Experiential Education Award from the University of New Haven for her service learning course and work as faculty advisor for Engineers Without Borders.

Qing (Cheryl) Li is Associate Professor of Mechanical Engineering at the University of New Haven. She earned her first PhD in mechanical engineering from the National University of Singapore and a second PhD in educational psychology, specializing in measurement, evaluation and assessment from the University of Connecticut. She has a unique cross disciplinary educational and research background in mechatronics engineering and educational psychology. Her research interests include design and control of mechatronic systems, vibration reduction using functional materials such as piezoelectric material and electrical circuitry synthesis, application of AI for statistical analysis, and assessment in engineering education.

APPENDIX

Rubric for Assessing E-Learning Module Outcomes

Module: **Learning from failure**

Description of Integration (task, activity, assignment, etc):

Module Assessment Outcomes

Select which outcomes were targeted via Assignment -->	Identified mistakes in the product or process development cycle	Suggested options to correct mistakes that occured in the activity	Explained the potential risks of failure	Proposed solutions to address risks
RATING:	1--> Poor, 2--> Below Average, 3--> Average, 4--> Above Average, 5--> Outstanding			
Student #				
1				
2				
3				
4				
5				
6				
7				
8				

Select student assignment related to the integration of the e-learning module in your course. Using that assignment, assess each student's level of attainment of the selected module outcomes.

Use the following rating:

1: Poor: Shows little or no progress in achieving outcome

2. Below Average

3. Average: Shows evidence of progress in achieving outcome that reflects a merely acceptable level of mastery

4. Above Average

5. Outstanding: Shows evidence of progress in achieving outcomes that reflects superior mastery

Questions: please email keen@newhaven.edu

Thank you.

Figure A–1. Assessment rubric for Learning from Failure module.

Table A–1. Pilot External Deployment in Spring 2016.

Module	Institution	Course
Applying Systems Thinking to Solve Complex Problems	Lafayette College	ME 391: Independent Study - Robotics and Mechatronics
	Villanova University	ChE 4131: Process Design I
Building, Sustaining and Leading Effective Teams and Establishing Performance Goals	University of Dayton	ECT 110: Electrical Circuits
The Elevator Pitch: Advocating for Your Good Ideas	Santa Clara University	BIOE 111: Bioengineering Innovation and Design
Learning from Failure	Lafayette College	ES231: Natures of Engineering Materials
	Lafayette College	ChE 320/321: Applied Fluid Flow and Heat Transfer
	Ohio Northern University	ECCS 4721: Senior Design 2
Thinking Creatively to Drive Innovation	Villanova University	ME 3100: Thermodynamics

Table A–2. Large-Scale External Deployment at AY 2016–2017.

Module	Institution	Course
Applying Systems Thinking to Solve Complex Problems	California State University	MECH 432: Energy Systems
	Western New England University	IE 326: Production Planning and Control
	Ohio Northern University	ECCS 4731: Capstone Seminar
Building, Sustaining and Leading Effective Teams and Establishing Performance Goals	Lawrence Technological University	EGE 2123: Entrepreneurial Engineering Design Studio
	Manhattan College	CIVL 409: Concrete Design
	Tulane University	CENG 3240: Unit of Operations Laboratory
	Michigan Technological University	ENG1102: Engineering Modeling and Design
The Elevator Pitch: Advocating for Your Good Ideas	University of Texas at Dallas	MECH 1208: Intro to Mechanical Engineering II
	University of Cincinnati	EECE 5001/5031, 5002/5032, EE/CompE: Senior Design
	San Francisco State University	ENGR 425: Reinforced Concrete Structures
	University of Virginia	STS 1500: Sci, Tech. and Contemporary Issues
Learning from Failure	Rose-Hulman Institute of Technology	CE336: Soil Mechanics
	Embry-Riddle Aeronautical University	EGR 101: Introduction to Engineering
	Ohio Northern University	ECCS 4731: Capstone Seminar
Thinking Creatively to Drive Innovation	Villanova University	ME 5130: Introduction to Sustainable Energy
	Grand Valley State University	EGR 401: Advanced Product Design
	Pennsylvania State University	ENGR 407: Technology-Based Entrepreneurship
	Santa Clara University	BIOE 174: Microfabrication for Microfluidics
	James Madison University	ENGR 498: Innovation
	University of the Pacific	EMGT 142-Design and Innovation
	University of Connecticut	ME 3295/MSE 4095: Introduction to 3D Printing: Learn by Building
Establishing the Cost of Production or Delivery of a Service, Including Scaling Strategies	Ohio Northern University	ME 3421: Manufacturing Processes
	University of Alabama at Birmingham	EE 485/585: Engineering Operations
	Wichita State University	IME 255: Engineering Economy

Table A–3. Large-Scale External Deployment at AY 2017–2018.

Module	Institution	Course
Applying Systems Thinking to Solve Complex Problems	University of Denver	ENGR 3313: Engineering Design I
	University of the Pacific	BENG 195: Senior Project
	West Virginia University Institute of Technology	EE 434: Alternative Energy Resources
	University of Arkansas Little Rock	CPSC 4384/5383: Artificial Intelligence
Building, Sustaining and Leading Effective Teams and Establishing Performance Goals	University of Alabama at Birmingham	HC 111: Engineering Honors Seminar
	University of South Florida	EIN 4453/6936: Advanced Lean Six Sigma
	University of the District of Columbia	ELEC 351: Electronics
	West Virginia University Institute of Technology	MAE 331: Fluid Mechanics
	Wichita State University	ENGT 510: Solar and Wind Engineering
	Santa Clara University	BIOE 194: Design Project I.
The Elevator Pitch: Advocating for Your Good Ideas	Rose-Hulman Institute of Technology	EngD 100: Engineering Design Studio I
	University of San Diego	ENGR 494: Engineering Peace
	University of Wyoming	COSC 4950/4955: Senior Design I/II
	University of Texas at Dallas	MECH 1208: Introduction to Mechanical Engineering II
Thinking Creatively to Drive Innovation	Florida International University	BME 4908: Senior Design Project
	Georgia Institute of Technology	COE 2701: Startup Lab: Introduction to Technology Ventures
	University of Arkansas - Little Rock	SYEN 4386: Capstone Design II
	University of California - Davis	Eng 098: Intro to Entrepreneurship
	Valparaiso University	ECE 490: DI/Innovation in Engineering
	Western New England University	ME 303: Thermodynamics I
	Santa Clara University	BIOE 111: Opportunity identification and concept generation
Learning from Failure	University of the District of Columbia	CVEN 435-01: Foundation Design
	Weber State University	EE 485/585: Engineering Operations
	Santa Clara University	BIOE 196: Design Project III
	Lehigh University	Engr 5: Introduction to Engineering
Establishing the Cost of Production or Delivery of a Service, Including Scaling Strategies	University of Illinois Urbana-Champaign	Engineering 198: IEFX Projects
Developing a Business Plan that Addresses Stakeholder Interests, Market Potential and Economics	Fairfield University	MOT 591: Capstone
	Hofstra University	CSC 194-01: Foundations of Leadership and Innovation in Computing
	Villanova University	ME 5500: Biomechanics
	Santa Clara University	BIOE 112: BioInnovation II: Product Development and Prototyping
Adapting a Business to a Changing Climate	Trine University	EDE 4001: Contemporary Issues for Engineers
	University of Colorado Boulder	EMEN 3010: Introduction to Engineering Management