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Integrated e-Learning Modules for Developing an Entrepreneurial Mindset: Direct Assessment of Student Learning

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Maria-Isabel Carnasciali is an Associate Professor of Mechanical Engineering at the Tagliatela College of Engineering, University of New Haven, CT. She obtained her Ph.D. in Mechanical Engineering from Georgia Tech in 2008. She received her Bachelors of Engineering from MIT in 2000. Her research focuses on the nontraditional engineering student – understanding their motivations, identity development, and impact of prior engineering-related experiences. Her work dwells into learning in informal settings such as summer camps, military experiences, and extra-curricular activities. Other research interests involve validation of CFD models for aerospace applications as well as optimizing efficiency of thermal-fluid systems.

Dr. Ronald S. Harichandran, University of New Haven

Ron Harichandran has served as the Dean of the Tagliatela College of Engineering at the University of New Haven since August 2011. He is the PI of the grant entitled Developing Entrepreneurial Thinking in Engineering Students by Utilizing Integrated Online Modules and Experiential Learning Opportunities. Through this grant from the Kern Family Foundation, entrepreneurial thinking is being integrated into courses spanning all four years in seven ABET accredited engineering and computer science BS programs.

Dr. Nadiye O. Erdil, University of New Haven

Nadiye O. Erdil, an assistant professor of industrial and systems engineering and engineering and operations management at the University of New Haven. She has over eleven years of experience in higher education and has held several academic positions including administrative appointments. She has experience in teaching at the undergraduate and the graduate level. In addition to her academic work, Dr. Erdil worked as an engineer in sheet metal manufacturing and pipe fabrication industry for five years. She holds B.S. in Computer Engineering, M.S. in Industrial Engineering. She received her Ph.D. in Industrial and Systems Engineering from Binghamton University (SUNY). Her background and research interests are in quality and productivity improvement using statistical tools, lean methods and use of information technology in operations management. Her work is primarily in manufacturing and healthcare delivery operations.

Dr. Jean Nocito-Gobel, University of New Haven

Jean Nocito-Gobel, Professor of Civil & Environmental Engineering at the University of New Haven, received her Ph.D. from the University of Massachusetts, Amherst. She has been actively involved in a number of educational initiatives in the Tagliatela College of Engineering including KEEN and PITCH, PI of the ASPIRE grant, and is the coordinator for the first-year Intro to Engineering course. Her professional interests include modeling the transport and fate of contaminants in groundwater and surface water systems, as well as engineering education reform.

Dr. Cheryl Q. Li, University of New Haven

Cheryl Qing Li joined University of New Haven in the fall of 2011, where she is Associate Professor of the Mechanical and Industrial Engineering Department. Li earned her first Ph.D. in mechanical engineering from National University of Singapore in 1997. She served as Assistant Professor and subsequently Associate Professor in mechatronics engineering at University of Adelaide, Australia, and Nanyang Technological University, Singapore, respectively. In 2006, she resigned from her faculty job and came to Connecticut for family reunion. Throughout her academic career in Australia and Singapore, she had developed a very strong interest in learning psychology and educational measurement. She then opted for a second Ph.D. in educational psychology, specialized in measurement, evaluation and assessment at University of Connecticut. She earned her second Ph.D. in 2010. Li has a unique cross-disciplinary educational and research background in mechatronics engineering, specialized in control and robotics, and educational psychology, specialized in statistical analysis and program evaluation.

Integrated e-Learning Modules for Developing an Entrepreneurial Mindset: Direct Assessment of Student Learning

Abstract

In an effort to develop an entrepreneurial mindset in all our engineering and computer science students, the University of New Haven is embedding entrepreneurial concepts throughout the 4-year curricula in their majors. This is done with the use of several short e-learning modules developed by content experts. The modules are integrated into engineering and computer science courses by faculty who reinforce concepts through a related activity, project, or assignment. The e-learning modules, available online through course management systems, are self-paced and targeted at conceptual learning of 18 specific entrepreneurial topics. Using a flipped-classroom instructional model, students complete the modules outside of class, typically over a set two-week period, and instructors engage the students in discussion either in-class or online and through an activity. This mode of integration enables the assessment of higher cognitive understanding of the concepts and students' ability to apply what they learn.

At present, 12 modules have been developed. In addition to the modules being integrated within the University, they have also been adopted by faculty at 42 other institutions across the country over the past three years. The broad-scale deployment has provided assessment and feedback data regarding the effectiveness of integrating the modules into existing courses using a blended approach (face-to-face and online learning).

Whereas prior work relied on indirect assessment using pre/post student surveys to quantify the acquisition of knowledge from the e-learning modules and contextual activities, the current work employs student deliverables that are directly assessed by instructors. Faculty were provided assessment rubrics based on criteria aligned with the learning outcomes of the e-learning modules. Direct assessment is tangible, visible and measurable, and provides more compelling evidence of student learning. In this paper we propose an *Entrepreneurial Mindset Learning Index* to map and quantify the progress of students toward attaining an entrepreneurial mindset.

The criteria in the assessment rubrics for the e-learning modules were mapped to the learning outcomes associated with an entrepreneurial mindset proposed by the Kern Entrepreneurial Engineering Network's (KEEN) framework. The KEEN framework is based on the premise that an entrepreneurial mindset is characterized by a persistent *curiosity* of all things, the skills to make *connections* between seemingly unrelated things, and an ever-present goal to *create value*. Through the mapping, the direct assessment results provided an indication of how well students taking courses with integrated e-learning modules achieved elements of an entrepreneurial mindset.

Introduction

Students today must be ready to adapt to an ever-changing, interdisciplinary, and competitive world. The education they receive must go beyond the topics and skills that have formed part of engineering and computer science curricula for decades. Many have suggested that programs should equip students and graduates with entrepreneurial knowledge and skills that will enable them to contribute to the economic growth of our society – be it as intrapreneurs within companies and corporations, or as entrepreneurs themselves [1].

Models for adding entrepreneurial content to engineering curricula have begun to surface in the last 10-20 years. Two common models are: (1) partnerships with business programs for minors and dual-degrees; and (2) business-topics courses targeted specifically at engineering and science students [2]. An alternate model is being tried at the University of New Haven. In an effort to develop an entrepreneurial mindset in all our engineering and computer science students, the University of New Haven is integrating entrepreneurial concepts throughout the 4-year curricula in their majors using e-learning modules. Details of the motivation, development and integration have been the primary focus of prior papers [3, 4]. An advantage of this model is that it can be implemented within existing curricula for engineering and computer science majors, many of which lack flexibility to enable students to take additional courses. The e-learning modules, developed by content experts, serve as additional resources for the faculty teaching engineering and computer science courses and eliminates the need for these faculty to learn and present material outside of their expertise. The faculty then reinforce concepts through a related activity, project, or assignment. The e-learning modules are made available to the students online through the course management system used at the particular campus and for the course. The e-learning modules are meant to be self-paced and target conceptual learning of 18 specific entrepreneurial topics [Appendix A]. Using a flipped-classroom instructional model, students complete the modules outside of class, typically over a set two-week period, and instructors engage the students in discussion either in-class or online and through an activity/assignment that links the content of the module to a topic covered in the course. This mode of integration provides ample opportunity to reinforce concepts traditionally not included in engineering and computer science curricula.

Our model offers an additional pathway for exposing and equipping students with entrepreneurial knowledge by integrating the concepts within current engineering and computer science courses. Previous assessment of our model was based on indirect measures of student learning. The work presented here proposes a method for quantifying direct assessment of students' entrepreneurial mindset development within the integrated e-learning modules model.

Background

Our long-term goal is to develop an *entrepreneurial mindset* as defined by the framework proposed by the Kern Entrepreneurial Engineering Network (KEEN). The KEEN framework [5] is based on the premise that an entrepreneurial mindset is characterized by a persistent *curiosity*

of all things, the skills to make *connections* between seemingly unrelated things, and an ever-present goal to *create value*. The dimensions of *curiosity*, *connections*, and *creating value* are often referred to as the 3C's. In addition to these three dimensions, the KEEN framework adds *opportunity* and *impact* as complementary skills within the realm of the *entrepreneurial mindset*. The framework provides specific learning outcomes for the five dimensions; see Table 1.

Table 1: KEEN Framework

Dimension	Entrepreneurial Minded Learning Outcome	LO#
CURIOSITY	Demonstrate constant curiosity about our changing world	LO1
	Explore a contrarian view of accepted solutions	LO2
CONNECTIONS	Integrate information from many sources to gain insight	LO3
	Assess and manage risk	LO4
CREATING VALUE	Identify unexpected opportunities to create extraordinary value	LO5
	Persist through and learn from failure	LO6
OPPORTUNITY	Identify an opportunity	LO7
	Investigate the market	LO8
	Create a preliminary business model	LO9
	Evaluate technical feasibility, customer value, societal benefits, economic viability	LO10
	Test concepts quickly via customer engagement	LO11
	Assess policy and regulatory issues	LO12
IMPACT	Communicate an engineering solution in economic terms	LO13
	Communicate an engineering solution in terms of societal benefits	LO14
	Validate market interest	LO15
	Develop partnerships and build a team	LO16
	Identify supply chains distribution methods	LO17
	Protect intellectual property	LO18

The modules were first integrated at the University of New Haven. To demonstrate the potential for wider use of the integration model and the e-learning modules, a large-scale mini-grant program was put in place. Data regarding the use of the model is being collected not only at the University of New Haven but also at various institutions throughout the country. Faculty at other institutions have applied and been selected to integrate and deploy the e-learning modules into their own courses. The module content is made available in downloadable common course

cartridges (files), which can then be uploaded into the learning management system at other universities (e.g., Blackboard, Canvas, Desire2Learn, Sakai, iLearn, etc.). In spring 2016, six faculty from five institutions (not including the University of New Haven) participated; the following academic year, 2016-17, twenty-four faculty participated in the mini-grant program. Data collected up to that point included indirect assessment based on student responses to pre/post surveys. The results, presented at ASEE 2017 [3], suggested some evidence of the effectiveness of using the integrated e-learning modules. To address the shortcomings of the indirect assessment method, starting in fall 2017, we implemented a direct assessment method. In the sections that follow we present the results collected for one of the modules deployed and propose an *Entrepreneurial Mindset Learning Index* to quantify how well students achieved the KEEN Learning Outcomes through the integrated e-learning modules approach.

Fall 2017 Deployment

Internal Deployment

During fall 2017, broader integration of the e-learning modules at the University of New Haven occurred. In total 8 modules were deployed across 13 different courses involving 23 different instructors.

External Deployment

In addition to the internal deployment, the e-learning modules are being used by numerous instructors at various other universities/colleges. Following the success of the 2016-17 mini-grant program [3], in AY2017-18 we are conducting another mini-grant program similar to that conducted during AY2016-17. We issued a request for participation application for the AY2017-18 program in early spring 2017. Selection of participants was based on maximizing the number of different modules deployed; priority was given to faculty from institutions that had not previously participated. 26 faculty members from 24 universities/colleges that had not participated before were selected for the program, and 22 of these deployed modules during fall 2017.

Direct Assessment

As with any new approach, it is important to demonstrate the effectiveness of the integrated e-learning modules in developing an entrepreneurial mindset in engineering and computer science students. While quantifiable evidence of the long term (e.g., 5-10 years after graduation) impact of the educational experience of our students is outside the scope of our current work, evidence of them learning entrepreneurial content in a particular course through the integrated e-learning approach is attainable. Evidence attained through direct assessment methods is the strongest form of assessment. Direct assessment of student learning requires a standard of performance identified for a specific learning outcome. The standard of performance, or metric, is seen as tangible, and measurable, and tends to be more compelling evidence of exactly what students have and have not learned [6, 7].

In order to assess the effectiveness of the integrated e-learning modules approach, we developed a set of rubrics that instructors could use to directly assess student learning. The learning outcomes for each e-learning module were reviewed, revised if needed, and cast into three to five assessment outcomes that could be defined, understood, observed and measured. The assessment outcomes for the *Thinking Creatively to Drive Innovation* module deployed during fall 2017 are summarized in Figure 1 and Table 3.

We then requested faculty deploying the modules to assess student work on the contextual project or assignment related to a module using the related rubric. The rubrics employ a rating scale from 5–Outstanding to 1–Poor. If the assignment or task did not cover any of the assessment outcomes, the instructor was to label it as NA. The rubric used for the *Thinking Creatively to Drive Innovation* e-learning module is presented in Figure 1.

Rubric for Assessing E-Learning Module Outcomes					
Module: Thinking Creatively to Drive Innovation					
Description of Integration (task, activity, assignment, etc):					
Module Assessment Outcomes					
	Articulated creative component of work		Reflected on the source of creativity (nurture vs. nature)		Applied divergent-convergent thinking process to converge on a solution
	Applied an ideation technique to generate solutions (Ask-Ask-Ask method, Fishbone Diagram or Mind Mapping method)				
Select which outcomes were targeted via Assignment →					
RATING:	1--> Poor, 2--> Below Average, 3--> Average, 4--> Above Average, 5--> Outstanding				
Student #					
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					

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

Figure 1. Rubric used in courses which deployed the Thinking Creatively to Drive Innovation module

Table 2 provides a summary and description of the university/class settings that deployed the *Thinking Creatively to Drive Innovation* e-learning module, and the number of data points acquired. For the purposes of research, the names of the institutions are not used.

The direct assessment results submitted by the various instructors indicate that on average, students show evidence of acceptable progress in achieving the outcomes, with the mean of each Assessment Outcome (AO) being greater than 3. Table 3 shows the means and the standard deviation for the data in aggregate for a total of 145 assessments. Figure 2 shows the breakdown of the assessment ratings by class. The greatest scatter is seen in the first two outcomes which address students' *understanding* of creativity with lower values seen in the first-year courses (U1a-e).

Table 2: Fall 2017 Deployment of Thinking Creatively to Drive Innovation module

ID Name	Institution Description	Course Description	Level	No. Students
U1a	Comprehensive	College of Engineering; Introduction to Engineering	1st year	16
U1b	Private University;			19
U1c	Predominately			17
U1d	Undergraduate;			16
U1e	Northeast			17
U2	Highest Research; Public University; South	College of Engineering; Elective on Social Innovation	all except 1st year	15
U3	Moderate Research; Public University; South	Systems Engin.; Capstone course	4th year	6
U4	Highest Research; Public University West Coast	College of Engineering; Campus-wide elective; Intro to Entrep.	all	23
U5	Comprehensive Private University; Predominately Undergraduate; Midwest	Electrical & Computer Engineering, Elective on Innovation	3rd or 4th Year students	16

The results were not analyzed for *statistical significance* given the variety of deliverables instructors employed. Although the student deliverables varied based on instructor/class, the assessment instrument used by all instructors was identical. Looking at the details of the deliverables that were assessed, nearly all comprised of having the students tackle a design-like project, employing the techniques for idea generation presented in the module, and having them conceptualize the meaning of creativity. One instructor had students report via oral presentations (U2); another assessed engineering portfolios (U5); the 5 sections at U1 used student reflections; while the rest (U3, U4) had students submit written reports.

Table 3: Summary of assessment results provided from all Thinking Creatively to Drive Innovation deployments

	Assessment Outcome	Mean	StDev
AO1	Articulate creative component of work	3.42	1.3
AO2	Reflect on the source of creativity (nurture vs. nature)	3.28	1.4
AO3	Apply divergent-convergent thinking process to converge on a solution	3.92	1.1
AO4	Apply an ideation technique to generate solutions	3.91	1.0

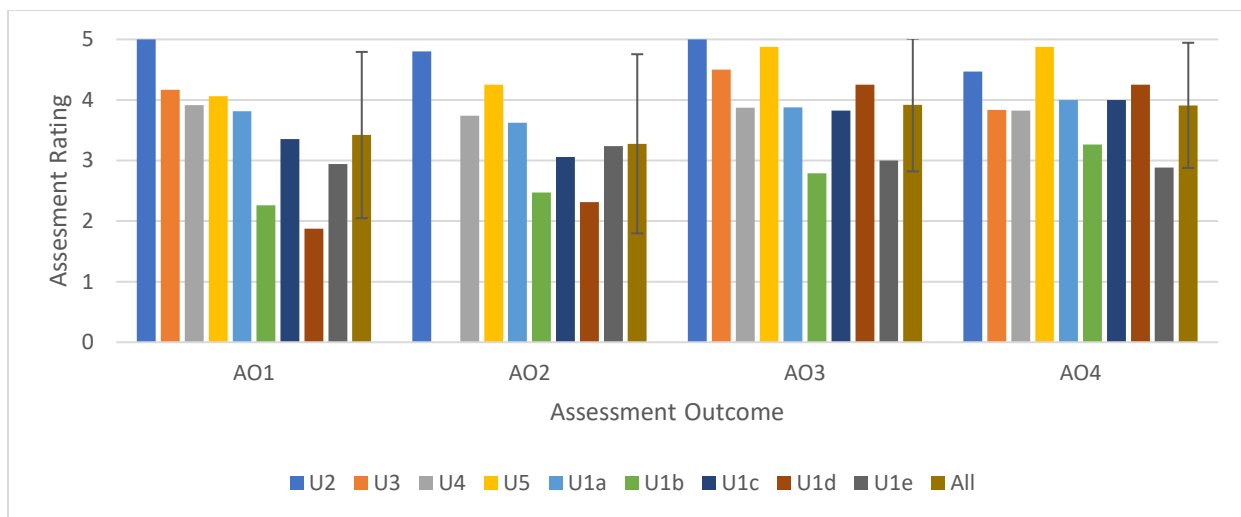


Figure 2. Average of direct assessment results provided by each instructor deploying Thinking Creatively to Drive Innovation module during Fall 2017

Mapping Direct Assessment to Entrepreneurial Minded Learning Outcomes

If we define *entrepreneurial mindset* based on the KEEN framework, then to assess students' achievement of the mindset one must be able to assess the various dimensions of the framework. Yet, each of the dimensions is complex and there is no single way to define/develop/assess it. Of the e-learning modules developed, each includes some of the 18 EM Learning Outcomes, but none includes all of them. In addition, the depth of coverage of the various EM Learning Outcomes included in any individual e-learning module varies, so a mapping was created to show the depth of coverage of each module. As an example, the EM Learning Outcomes highlighted in green in Table 4 are covered by the *Thinking Creatively to Drive Innovation* e-learning module, and the depth of coverage of those outcomes is indicated in the rightmost column of the table.

Next, a mapping was created for each Assessment Outcome (AO) to each EM Learning Outcome (LO). To increase reliability, this was done independently by three faculty in the research team and then consensus was reached through discussion. The resulting mapping for the *Thinking Creatively to Drive Innovation* module is displayed in Table 5. The first two AOs (AO1 and AO2) do not map to an EM Learning Outcome but help us evaluate foundational skills with respect to creativity. This knowledge is beneficial for providing background information should there be a concern related to student performance in AO3 and AO4.

Table 4: Depth of coverage related to EM Learning Outcomes provided by the Thinking Creatively to Drive Innovation module

Dimension	Entrepreneurial Minded Learning Outcome	Depth
CURIOSITY	Demonstrate constant curiosity about our changing world	High
	Explore a contrarian view of accepted solutions	Low
CONNECTIONS	Integrate information from many sources to gain insight	Medium
	Assess and manage risk	NA
CREATING VALUE	Identify unexpected opportunities to create extraordinary value	Medium
	Persist through and learn from failure	NA
OPPORTUNITY	Identify an opportunity	Medium
	Investigate the market	NA
	Create a preliminary business model	NA
	Evaluate technical feasibility, customer value, societal benefits, economic viability	NA
	Test concepts quickly via customer engagement	NA
	Assess policy and regulatory issues	NA
IMPACT	Communicate an engineering solution in economic terms	NA
	Communicate an engineering solution in terms of societal benefits	NA
	Validate market interest	NA
	Develop partnerships and build a team	NA
	Identify supply chains distribution methods	NA
	Protect intellectual property	NA

Table 5: Mapping of Assessment Outcomes (AO) to Entrepreneurial Minded Learning Outcomes (LO) for the Thinking Creatively to Drive Innovation module.

Dimension	LO	AO3 Apply divergent-convergent thinking process to converge on a solution	AO4 Apply an ideation technique to generate solutions
CURIOSITY	Demonstrate constant curiosity about our changing world	High	High
	Explore a contrarian view of accepted solutions	Medium	-
CONNECTIONS	Integrate information from many sources to gain insight	-	High
CREATING VALUE	Identify unexpected opportunities to create extraordinary value	Medium	Medium
OPPORTUNITY	Identify an opportunity	Medium	Medium

The EM Learning Index

We propose an *EM Learning Index* to quantify how much of a particular EM Learning Outcome students learned from an integrated e-learning module based on the ratings provided by instructors for the Assessment Outcomes.

The *EM Learning Index*, $i_{e,m}$, for each learning outcome (represented by e) and for each module (represented by m), is defined by Equation 1,

$$i_{e,m} = 100 \sum_{n=1}^s \sum_{q=1}^t \frac{w_{e,m,q} a_{e,m,q,n}}{15st} \quad (1)$$

where

$w_{e,m,q}$ = weight assigned to EM Learning Outcome e , for module m and assessment outcome q ,

$a_{e,m,q,n}$ = assessment rating assigned by the instructor for student n for EM learning outcome e , module m , and assessment outcome q ,

s = number of students assessed in each class,

t = number of assessment outcomes for module m ,

and

$(e = 1, \dots, 18), (m = 1, \dots, 18), (q = 1, \dots, t), (n = 1, \dots, s)$.

The number of assessment outcomes (t) for each module typically varies between 3 and 5; $w_{e,m,q}$ can have values of 0 (not addressed at all), 1 (low), 2 (medium) or 3 (high). For $a_{e,m,q,n}$, as previously stated, the instructors were asked to use a rating of 1 to 5, and 0 for NA. The factor of 15 which appears in the denominator arises from the fact that 15 is the maximum value of any one factor (i.e., maximum depth coverage for an AO is 3; maximum assessment rating assigned

to each AO is 5). The *EM Learning Index* for any single learning outcome will vary from 0 to 100, with 100 being obtainable when all AOs are mapped at a high level of depth (3) and the student receives a rating of 5 for all AOs.

The maximum value of the *EM Learning Index* for a given module and EM Learning Outcome is

$$i_{e,m,max} = 100 \sum_{q=1}^t \frac{w_{e,m,q}}{3t} \quad (2)$$

Table 6 shows the maximum value of the *EM Learning Index* for the five EM Learning Outcomes covered by the *Thinking Creatively to Drive Innovation* module.

Table 6: EM Learning Index for Thinking Creatively to Drive Innovation module

Dimension	LO	EM Learning Index Max Value
CURIOSITY	e1	50
	e2	16.7
CONNECTIONS	e3	25
CREATING VALUE	e5	33.3
OPPORTUNITY	e7	33.3

The *EM Learning Index* for students in each of the classes that deployed the *Thinking Creatively to Drive Innovation* module in fall 2017 is shown in Figure 3. The variation from class to class can arise from one or more of the following sources:

- The effectiveness of the contextual activity in reinforcing what students learned in a module
- The effectiveness of the instructor in integrating the e-learning module into the course
- The class size
- The propensity of the instructor to assign high or low assessment ratings for the deliverables of the contextual activity
- The ability of the students in the class

For example, institution/class U5 had the highest *EM Learning Index* for each EM Learning Outcome, each of which was very close to the maximum possible index value. This could be due to a combination of having high performing students, a well-designed contextual activity, and/or the instructor being an "easy" grader. In general, the trends in the *EM Learning Index* from one class/instructor to another are consistent for all EM Learning Outcomes, which is a result of Assessment Outcomes being mapped across several EM Learning Outcomes. High ratings for an Assessment Outcome will therefore translate across the EM Learning Outcomes to which it is mapped.

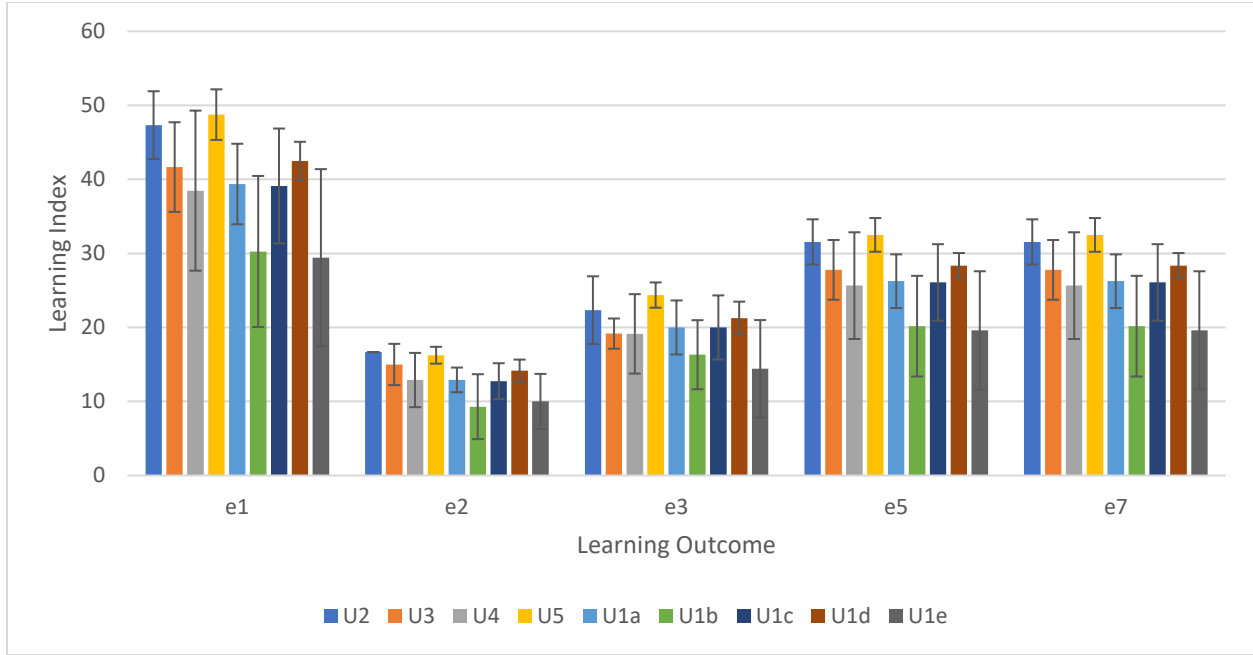


Figure 3. Learning Index for Learning Outcomes addressed by the Thinking Creatively to Drive Innovation

The effectiveness of an e-learning module in enabling students to learn elements of an EM Learning Outcome that it contains can be characterized by the *EM Learning Effectiveness Index*, $E_{e,m}$, as described by Equation 3.

$$E_{e,m} = 100 \frac{i_{e,m}}{i_{e,m,max}} \quad (3)$$

A module that only partially covers elements of an EM Learning Outcome will have the corresponding $i_{e,m,max}$ be less than 100 as shown in Table 6, and the $i_{e,m}$ value will be less than $i_{e,m,max}$ as shown in Figure 3. However, the normalized $E_{e,m}$ will always be between 0 and 100. The *EM Learning Effectiveness Index* values for the *Thinking Creatively to Drive Innovation* module are summarized in Figure 4.

Figure 4 shows the variation amongst the different instructors and courses. Across all Assessment Outcomes for the *Thinking Creatively to Drive Innovation* module, the highest levels were consistently obtained by external deployments (i.e., non-University of New Haven). Of these, both U2 and U5 were also at KEEN partner institutions like U1 (University of New Haven), whereas U3 and U4 were deployments by faculty unfamiliar with the KEEN initiative. In comparison, U1 a-e represent 5 deployments within our institution in different sections of the same course, with the same deployment/ integration strategy, and the same assignment for assessment purposes. Of these, U1c represents a faculty member closely involved with the efforts to integrate EM at our institution. This faculty member serves as the course coordinator, setting the pace and expectations other faculty teaching the same course must follow. This faculty member mentored closely the instructor of section U1a; this section was taught by a first-

time adjunct faculty. The results hint that the integration into these two sections was equally effective and suggest that closer oversight of how the other faculty are deploying/integrating the module into their sections may be necessary. The lower indices for section U1b cannot be credited to a tougher instructor given that section U1d was taught by the same instructor. In addition, the instructors of sections U1b/d and U1e have both participated in training related to the integration of EM into the curriculum (KEEN ICE Workshops). Although interrater reliability was not investigated in this study, the results within the University of New Haven will help us to identify areas for improvement such as training for faculty deploying and assessing the use of modules or students who need further enrichment.

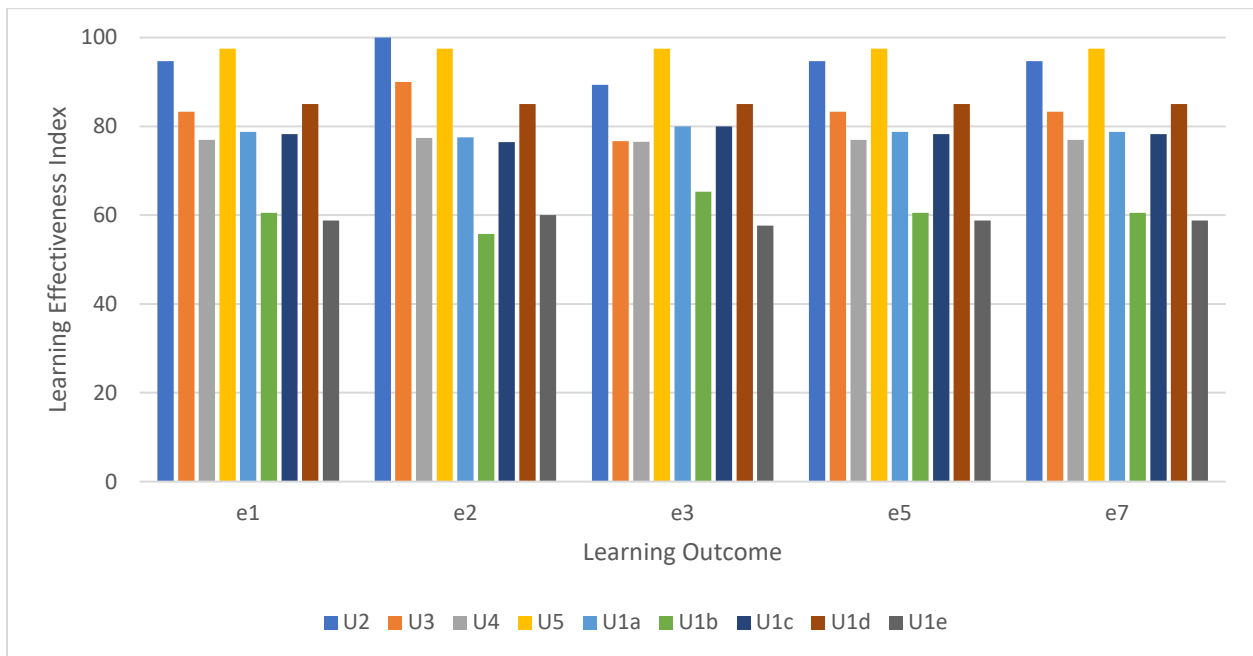


Figure 4. Effectiveness of Thinking Creatively to Drive Innovation module deployment, Fall 2017

As this illustration indicates, the Learning Effectiveness Index can be used to identify how well students in a particular class achieved the Assessment Outcomes, which depends on the effectiveness of instructors and the contextual reinforcing activities employed. We will examine this index for the deployment of all e-learning modules at our institution to identify effective deployment and reinforcing activities and to help instructors and students gain from these experiences.

Summary and Future Work

An approach for directly assessing student learning that takes place through e-learning modules that are integrated into engineering and computer science courses is described. This approach was used by faculty at the University of New Haven and at other universities and colleges who

deployed modules in fall 2017 and spring 2018. An *EM Learning Index* and an *EM Learning Effectiveness Index* are proposed to quantify how well students achieve the EM Learning Outcomes in the KEEN Framework by completing any of the e-learning modules and the contextual activity that students work on after completing a module. This is done through the following steps:

1. A reduced set of Assessment Outcomes are developed for each module based on its content.
2. The Assessment Outcomes are mapped to the EM Learning Outcomes at levels of high, medium, low, or none.
3. Faculty rate student performance on the contextual activity related to the e-learning module deployed in their class.
4. The *EM Learning Index* is computed to characterize how much of the EM Learning Outcomes students in a class achieved on average.
5. The *EM Learning Effectiveness Index* is computed to assess how effective an e-learning module was in helping students learn the EM Learning Outcomes covered by that module.

Application of the proposed direct assessment approach in seven courses that integrated the *Thinking Creatively to Drive Innovation* module in fall 2017 is illustrated. The results indicate that the *EM Learning Index* and the *EM Learning Effectiveness Index* are useful measures of the student learning that took place by integrating the e-learning module in a course and allow for comparisons across instructors/courses.

More extensive analysis of results from the integration of other modules will be performed in the near future. The comparisons reported in this paper are preliminary and conclusions are limited due to the fact that the e-learning module was used by multiple faculty in different courses. A more robust comparison would require an interrater reliability study to fully ensure that the assessment rubrics designed are being consistently used. In addition, variations due to class size were not investigated. Segmenting the data collected based on class size may reveal whether learning effectiveness is compromised in large classes.

At the University of New Haven where students are taking multiple modules, we plan to aggregate across modules to assess an overall *EM Learning Index*, i_e , based on all modules students take that would be a measure of average student learning of EM Learning Outcomes by completing multiple modules. This overall index can be computed by Equation 4,

$$i_e = 100 \sum_{m=1}^M \sum_{n=1}^s \sum_{q=1}^t \frac{w_{e,m,q} a_{e,m,q,n}}{15Mst} \quad (4)$$

where M = number of modules completed. The *Overall Learning Index*, i_e , should be a useful measure of the level of entrepreneurial mindset our students attain, and in identifying additional content that might need to be introduced if specific i_e values are low.

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Appendix A: List of E-Learning Modules

Each e-learning module has a set of module specific learning outcomes. These outcomes are listed here. Module assessment outcomes (AO) for each module that are used in direct assessment are typically a subset of these learning outcomes.

Thinking Creatively to Drive Innovation

- Describe the meaning of creativity, a rare but achievable form of thinking
- Explain the observation that creativity is influenced much more by nurture than nature
- Describe the universality and power of the divergent-convergent thinking process
- Apply the Medici Effect when forming teams
- Apply the Ask-Ask-Ask method
- Apply the Fishbone Diagramming method
- Apply the Mind Mapping method

Learning from Failure

- List common mistakes in the product development cycle for real world projects
- Develop a list of practical options to correct or avoid potential mistakes that may occur in specific projects
- Explain the potential risks of failure and proposed solutions in terms familiar to various stakeholders
- Provide recommendations for deciding when to stop a project or when to continue it
- Extract practical lessons learned by reviewing case histories of failures

Cost of Production and Market Conditions

- Identify the market scenarios for a product
- Analyze the effects of different business models
- Describe the nature of the firm that will be best for the product and its environment
- Describe the behavior of costs in the short run and long run production
- Identify economies of scale and disc-economies of scale through long run cost curves
- Apply various methods to suggest a selling price based in the costs of production
- Describe different market structures
- State the characteristics of the long tail and internet markets

The Elevator Pitch: Advocating for Your Good Ideas

- Identify the value proposition of a product or service from the point of view of a variety of stakeholders
- Articulate the criteria that yield an effective pitch
- Outline a process for developing elevator pitches
- Implement strategies for recovering from an unsuccessful pitch experience

Building, Sustaining and Leading Effective Teams and Establishing Performance Goals

- Identify success factors at each stage of the team development process that influence productivity
- Differentiate between consensus and compromise
- Examine individual preferences' dichotomies found in a personality comparison instrument
- Identify factors that influence actions and decision-making
- Recognize four different viewpoints used to reach consensus
- Relate the importance of team and individual performance to reaching overall objectives
- Design a performance plan
- Identify ways to address conflicts in teams most productively

Applying Systems Thinking to Complex Problems

- Define system, systems architecture, and system engineering
- Decompose system hierarchy to at least four levels
- Define any system from various perspectives, including technical feasibility, value risk, and societal impact
- Describe four methods of developing a system architecture
- Apply the heuristic architecting method to develop a system architecture

Developing a Business Plan That Addresses Stakeholder Interest, Market Potential and Economics

- Identify an innovative and differentiated business concept
- Develop a strategy for returning value to economic stakeholders
- Construct a business's value chain, showing the company's operational flow
- Assess a business market opportunity, including competitive positioning
- Develop market entry, growth and exploitation strategy
- Develop key business plan assumptions and simulate business performance
- Utilize resources to prepare valuable business plans

Role of Production in Value Creation

- Describe each element of the total product concept
- Apply the Product concept to past product successes and failures
- Define the concept of value
- Explain the value proposition canvas
- Relate the Product concept to the value proposition canvas
- Evaluate value creation using the value proposition canvas

Adapting a Business to a Changing Climate

- Explain the ways in which new and existing firms are impacted by changing business conditions
- Describe the various factors that make up market/business conditions
- Perform environmental scanning on the business environment
- Describe ways in which firms deal with changes in its business environment
- Explain the mindset and characteristics of those people (and organizations) that survive and thrive given challenges and setbacks

Defining and Protecting Intellectual Property

- Classify valuable physical and intellectual assets
- Explain why intellectual property (IP) assets are important to a company's valuation and its stakeholders
- Employ methods to protect valuable trade secret and confidential information IP assets
- Use trademarks, industrial designs, and copyrights to protect brand value
- Describe how to file patents

Resolving Ethical Issues

- Assess, and later reassess, your position on an ethics scale
- Define ethics in the context of professional settings
- Explain why ethical behavior and the trust it engenders are essential for all engineers especially entrepreneurial engineers
- Analyze ethical dilemma case studies and explain who resolved them and how
- Apply three methods for resolving ethical dilemmas

Generating new ideas based on societal needs and business opportunities

- Differentiate between an idea and an opportunity
- Describe how to identify new business opportunities by observing social and environmental trends
- Recognize how to find business opportunities through identifying needs and offering viable potential solutions
- Explain how identifying gaps in the marketplace can lead to finding viable business opportunities
- Describe a variety of techniques that can generate ideas of value