An Approach to Assess Achievement of EML through Integrated e-Learning Modules

Dr. Ronald S Harichandran P.E., University of New Haven

Ron Harichandran is Dean of the Tagliatela College of Engineering and 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 entrepreneurial thinking has been integrated into courses spanning all four years in seven ABET accredited engineering and computer science BS programs.

Aadityasinh Rana,

Aadityasinh Rana graduated with an MS in Industrial Engineering with a concentration in statistical analysis from the University of New Haven. He received his bachelor's degree in Mechanical Engineering from Navrachana University, India. His thesis focused on direct assessment of EML via integrated e-learning modules. Currently he is working with Amazon as an Inventory Control and Quality assurance associate where he continues to strive for better improvements in the area of product quality.

Dr. Nadiye O. Erdil, University of New Haven

Nadiye O. Erdil, an associate professor of industrial and systems engineering and engineering and operations management at the University of New Haven. She has over twelve 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.

An Approach to Assess Achievement of EML through Integrated e-Learning Modules

Introduction

The University of New Haven promotes entrepreneurial minded learning (EML) through the integration of e-learning modules on entrepreneurial topics into regular engineering and computer science courses. Each module is supplemented by a contextual activity where students apply what they learned in the module. The e-learning modules collectively target 18 KEEN Student Outcomes (KSOs) described in the KEEN Framework [1]. Appropriate assessment methods are needed to determine whether the integrated e-learning modules are effective in developing students' entrepreneurial mindset.

Purzer, Fila and Nataraja provide a review of assessment methods in engineering entrepreneurship education [2]. Most studies on the general assessment of an entrepreneurial mindset (EM) have been based on personality instruments that were not specifically designed to assess EM. An extensive literature review and a new measure of EM—the Entrepreneurial Mindset Profile—is presented by Davis, Hall and Mayer [3]. A survey instrument to assess EM specifically tailored around the KEEN Framework was developed by Li, et al. [4] and Brunhaver, et al. [5]. These types assessments of EM are indirect measures based on survey instruments. If these are to be used to assess EM growth resulting from curricular or co-curricular intervention, then the surveys must be administered before and after the intervention.

While indirect assessment methods are commonly used and useful, direct assessment methods based on student work are stronger. Studies on the direct assessment of EM are much fewer than those on indirect assessment. Klein and Yoder proposed a rubric-based approach for assessing student artifacts [6]. Hylton and Hays modified VALUE rubrics to perform course level assessment of EM [7]. A method to assess student achievement of KSOs involving the computation of an Entrepreneurial Minded Learning (EML) Index was proposed by Harichandran et al. [8]. In this paper, an alternative and more traditional approach based on the proportion of students in a class achieving an acceptable score is developed.

The assessment method and the related statistical approach can be adapted to a broader context other than for assessing the development of EM through integrated e-learning modules. For example, many institutions assess achievement of ABET student outcomes based on student performance in course learning outcomes that are mapped to ABET student outcomes. The methods described in this paper can be used for such assessments with sound statistical justification.

E-Learning Modules, Contextual Activities and Assessment Outcomes

This study focuses on four modules deployed at the University of New Haven. The four modules and their abbreviations are listed in Table 1. Each module has a set of learning outcomes. For the purpose of assessment, 3-5 assessment outcomes (AOs) were proposed for each module and the contextual activities related to the content in the module and the course were developed based on these outcomes. The assessment outcomes for the four modules in Table 1are listed in Table 2. The rubrics were used by instructors to evaluate student performance on contextual activities and exam questions related to each module. The

Table 1. E-learning Modules Used for the Study

Module Name	**Short Name (Abbreviation)**
Thinking creatively to drive innovation	Thinking creatively (TC)
Learning from failure	Learning from failure (LFF)
Establishing the cost of production or delivery of a service, including scaling strategies	Cost of production (CoP)
Building, sustaining and leading effective teams and establishing performance goals	Effective teams (ET)

Table 2. Assessment Outcomes for the Four Modules

Module	**AO1**	**AO2**	**AO3**	**AO4**
Thinking Creatively	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)
Learning from Failure	Identified mistakes in the product or process development cycle	Suggested options to correct mistakes that occurred in the activity	Explained the potential risks of failure	Proposed solutions to address risks
Cost of Production	Analyzed the effects of different business models	Provided an estimate of cost and revenue for a product/process/ design for a set period	Compared different market structures (competitive, monopoly, oligopoly) in the context of the activity	
Effective Teams	Identified typical behaviors during the team development process that influenced productivity	Identified typical behaviors during the team development process that influenced productivity	Employed a written plan (such as a team charter or team performance plan) to help the team be effective	Proposed approaches to resolve conflicts

performance rating provided by the instructors ranged from 1 to 5, with 1=Poor, 2=Below Average, 3=Average, 4=Above Average and 5=Outstanding. Not all students included in this study completed all four modules. The assessment was done at the class level and not tracked by individual students. Each of the four modules was integrated into a different course. Student performance in the contextual activities contributed to their overall course grades, so they had an incentive to complete the modules and the contextual activities.

Instructors were trained at the beginning of each semester regarding the contextual activity that was to be used in each course. For first and second year common courses in which the TC, LFF and CoP modules were deployed, the contextual activity was specified by a course coordinator. For upper level disciplinary courses in which the ET module was deployed, instructors had the flexibility to come up with their own contextual activity. A brief description of the contextual activities for the four modules listed in Table 1 is given below:

- *Thinking Creatively*: Students are asked to implement one of the techniques for brainstorming related to their final course project in which they design a puzzle, and submit a reflection paper in which they discuss whether they think their creativity was enhanced by what they learned from the module, and how they were creative in designing the puzzle based on what they learning in the module about creativity.
- *Learning from Failure*: Students work in teams to complete a design project in which they control the movements of a robot which delivers parts from one platform to another in a workcell layout that the teams create collectively. They are asked to write reflections at the end of the project that address the failures they experienced during implementation and what could have been done differently to avoid them. They are also asked to discuss the potential risks of failure for a project like this in real life and propose solutions to mitigate them.
- *Cost of Production*: Students are asked to describe a product and a business model that they will adopt. They are expected to describe in detail why they chose that business model, the total cost of production for their products, target users, the market structure in which they will be selling the product and its impact on the business and their marketing strategy.
- *Effective Teams*: This module is deployed in various discipline specific courses; therefore, the technical assignments to which the contextual activities are linked differ significantly. However, the module-related tasks students are asked to complete are similar. The students typically complete a personality test to determine what role is best suited to each team member and prepare a team charter. They also write a reflection paper discussing the behaviors and emotions observed at each stage of their team's development period, any conflicts experienced during the project life cycle, and the approach used to resolve conflicts.

Relating Assessment Outcomes to KSOs

The AOs are different for each e-learning module. However, all of the e-learning modules were designed to address some of the 18 KSOs listed in Table 3.

The AOs for each module were mapped onto the KSOs by Harichandran et al. [8], with weights of 0, 1, 2 or 3 assigned to each KSO based on the depth of coverage of that KSO by the module. The mappings for the four modules included in this study are shown in Table 4; cells that are blank indicate a weight of zero.

Assessment of Learning for *Thinking Creatively* Module

Based on the ratings for each individual student for each of the assessment outcomes, the achievement of the AOs were assessed by setting a minimum threshold of '3=Average' for satisfactory performance. To quantify the achievement of each AO, the proportion of students scoring greater than or equal to the threshold limit of '3' was calculated. This is the proportion of students in the class who met or exceeded the threshold for satisfactory performance. Table 5 shows the proportion of students in the class who met or exceeded the threshold value of 3 for each AO of the *Thinking Creatively* module deployed in seven first-year course sections. The University of New Haven has small classes in order to provide an intimate learning environment and hence the sample sizes are small. The data is displayed graphically in Figure 1. The same

Table 3. KEEN Student Learning Outcomes (KSOs)

Dimension	KEEN Student Outcome	Abbreviation
CURIOSITY	Demonstrate constant curiosity about our changing world	Curiosity
	Explore a contrarian view of accepted solutions	Contrarian
CONNECTIONS	Integrate information from many sources to gain insight	Insight
	Assess and manage risk	Risk
CREATING VALUE	Identify unexpected opportunities to create extraordinary value	Value
	Persist through and learn from failure	Failure
OPPORTUNTIY	Identify an opportunity	Opportunity
	Investigate the market	Market
	Create a preliminary business model	B_Model
	Evaluate technical feasibility, customer value, societal benefits, economic viability	Feasibility
	Test concepts quickly via customer engagement	Customer
	Assess policy and regulatory issues	Policy
IMPACT	Communicate an engineering solution in economic terms	Economic
	Communicate an engineering solution in terms of societal benefits	Societal
	Validate market interest	Validate
	Develop partnerships and build a team	Team
	Identify supply chains distribution methods	S_Chain
	Protect intellectual property	IP

Table 4. Depth of Coverage of KSOs by Four E-Learning Modules

Module →	TC				LFF				CoP			ET			
	AO1	AO2	AO3	AO4	AO1	AO2	AO3	AO4	AO1	AO2	AO3	AO1	AO2	AO3	AO4
KSO ↓															
Curiosity			3	3											
Contrarian			2			1			1						
Insight				3			2	2	2	2	2	2	1	1	
Risk					3	3	3	3					1	1	1
Value			2	2					3						
Failure					3	3	3	3							
Opportunity			2	2					2						
Market									3		2				
B-model									1						
Feasibility					3	2	1	1	1	2	1				
Customer															
Policy											1				
Economic										3					
Societal															
Validate							1								
Team												3	3	3	3
S-chain															
IP															

Table 5. Proportion of students who performed satisfactorily on TC module AOs

Course Section	Sample Size	AO1	AO2	AO3	AO4
21a-TC-F17	16	38%	63%	100%	100%
21b-TC-F17	18	50%	67%	78%	100%
21-TC-F18	14	64%	64%	79%	79%
22-TC-F17	17	88%	76%	94%	94%
23-TC-F17	16	100%	100%	100%	100%
24-TC-F17	17	65%	76%	76%	65%
33-TC-F18	13	–	–	31%	100%

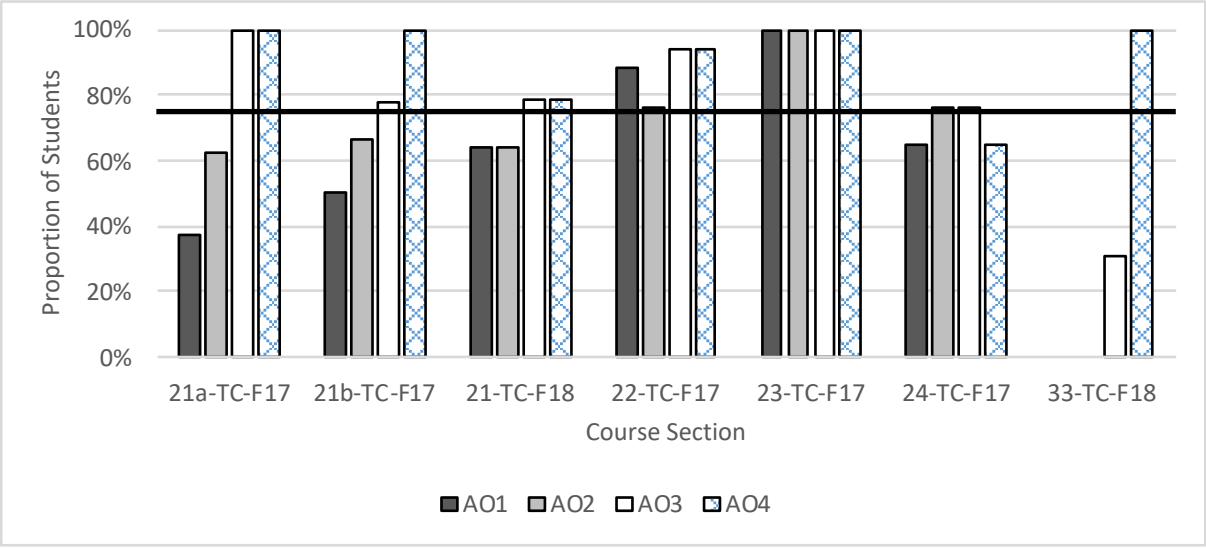

Figure 1. Proportion of students at or above the threshold for the TC module

contextual activity was used in all sections. The label for the course section has the form NN-TC-Fnn, where NN is a numeric code assigned to the instructor, TC indicates the Thinking Creatively module, and the Fnn indicates the semester (Fall '17 or Fall '18). Instructor 21 deployed the TC module in two sections and these are labeled as '21a' and '21b'.

The proportions in Table 5 and Figure 1 can be compared against a preestablished threshold, say 75%, to determine whether student performance in the class is satisfactory in an overall sense. The 75% threshold is shown as a thick line in Figure 1. The proportions for all AOs exceed 75% only for two course sections (22-TC-F17 and 23-TC-F17), while the proportions for some or all of the AOs fall short of 75% for the other five course sections. The following are some initial observations:

- Instructor 23 appears to have graded easily since all students in the class met or exceeded the threshold.
- Instructor 33 did not assess outcomes AO1 and AO2.

The ratings given to students by instructors reflect the following:

- The effectiveness of the contextual activity developed for the course; i.e., how well did the contextual activity address the AOs.
- How well students applied what they learned in the e-learning module onto the contextual activity.
- How "easy" or "hard" and instructor was when providing the ratings. For example, instructor 23 appears to have been very generous with the ratings.

In order to assess achievement of KSOs, the threshold (=3) for AOs was transformed to appropriate thresholds for KSOs by multiplying the threshold value (=3) for AOs with the weights shown in Table 4. The weights are shown again in Table 6. KSOs not addressed by the module are not shown. AO1 and AO2 were not related to the KSOs, so the weights for them are zero. The threshold values for each KSO can now be different depending on the weights.

The AO ratings provided by the instructor for each student were also transformed to an assessment rating for the KSOs using the same weights. If a student's achievement score for a KSO was at or above the threshold value, then the student's performance was deemed satisfactory. Since the threshold value varies from one KSO to another, it is convenient to normalize the student's achievement score by dividing it by the threshold value for the KSO. The student performance will then be considered satisfactory if the normalized achievement score is at or above 1.0. The student's normalized achievement score, $S_{k,m}$, for KSO k in module m can be expressed as

$$S_{k.m} = \sum_{j=1}^{t} \frac{a_{j,m} w_{k,j,m}}{3 w_{k,j,m}} \tag{1}$$

where $a_{j,m}$ = assessment rating for assessment outcome j in module m,
$w_{k,j,m}$ = weight assigned to KSO k for assessment outcome j in module m, and
t = number of assessment outcomes for module m

The proportion of students who met or exceeded the KSO threshold values in the seven course sections are shown in Table 7 and graphically displayed in Figure 2. Whether or not a course meets its goal of developing an entrepreneurial mindset can be ascertained by setting a minimum threshold, say 75%, for the proportion of students performing at a satisfactory level. The 75% threshold is shown as a thick line in Figure 2. Course sections 21-TC-F18, 24-TC-F17 and 33-TC-F18 fall short of the threshold of 75% for several or all KSOs.

Table 6. KSO Threshold Values for Thinking Creatively Module

KSO	Weights				Threshold Value
	AO1	AO2	AO3	AO4	
Curiosity			3	3	18
Contrarian			2		6
Insight				3	9
Value			2	2	12
Opportunity			2	2	12

Table 7. Proportion of Students at or Above KSO Thresholds for TC Module

KSO	Course Section						
	21a-TC-F17	21b-TC-F17	21-TC-F18	22-TC-F17	23-TC-F17	24-TC-F17	33-TC-F18
Curiosity	100%	78%	57%	94%	100%	65%	31%
Contrarian	100%	78%	79%	94%	100%	76%	31%
Insight	100%	100%	79%	94%	100%	65%	100%
Value	100%	78%	57%	94%	100%	65%	31%
Opportunity	100%	78%	57%	94%	100%	65%	31%

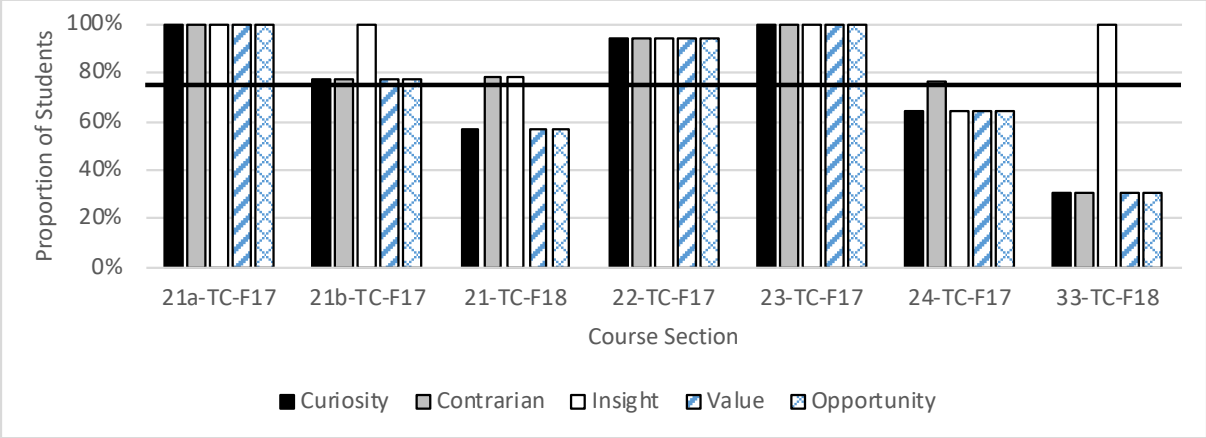

Figure 2. Proportion of students at or above KSO thresholds for TC module

Since only AO3 and AO4 contribute toward the KSOs, the heights of the bars in Figure 2 roughly conform to the heights of the second two bars within each group in Figure 1. The proportion of students who satisfactorily achieved the KSOs appears to be substantially different between some of the course sections. For example, there appears to be a substantial difference in student performance in the three course sections taught by instructor 21 (i.e., '21a' and '21b' and '21'). Instructor 33 rated students poorly for AO3, which translated to low ratings for four of the five KSOs.

Statistical Analysis of Student Performance

A simple comparison to determine that the proportion of students who performed at a satisfactory level did not meet the 75% threshold could be misleading. We must determine whether the shortfall from 75% is statistically significant or not.

The proportions for the course section 24-TC-F17 are analyzed to demonstrate how the confidence interval for a proportion can be used to determine statistical significance. The hypothesis to be tested is:

The proportion of students scoring at or above the threshold value for a given KSO is less than 75%. i.e.,

H_0: $p < 75\%$ (Null hypothesis)

H_a: $p \geq 75\%$ (Alternate hypothesis)

First, the following conditions for the test must be confirmed:

- Random condition: The samples must be randomly selected.
- Normal condition: Each sample must have at least 10 successes and 10 failures.
- The samples must be independent.

Many engineering classes at the University of New Haven are small and do not meet the normal condition. For example, there were 17 students in course section 24-TC-F17. From the data in Table 7, for the *Curiosity* KSO the number of successes = $17 \times 0.65 = 11.05$ and the number of failures = $17 \times 0.35 = 5.95 < 10$. Therefore, the method for normal approximation cannot be applied for the proportion test. In order to conduct the test, an alternative approach that is suitable for small sample sizes must be used. A suitable alternative approach is the Bootstrap Confidence Interval method [9].

The bootstrap approach overcomes the small sample size problem by generating multiple samples that mimic the behavior of the original sample and allows the distribution of a statistic such as the mean or the variance to be estimated [10, 11]. In other words, the original sample is used to resample (with replacement) and create a large number of new samples, all of which are used collectively to get a better idea about the population parameter studied based on its sampling distribution statistic. In this study, the bootstrap method was applied to the confidence interval estimate for the population parameter proportion (p) for one and two samples, and the publicly available software StatKey was used to produce interval estimate [12]. The proportion being less than the 0.75 threshold is not statistically significant if the 0.75 value lies within the 95% confidence interval (i.e., we fail to reject the null hypothesis), and is statistically significant only if the 0.75 value lies outside the confidence interval (i.e., the null hypothesis is rejected).

For the *Curiosity* KSO, the confidence interval for the 95% confidence level for the proportion for 1000 bootstrapped samples is shown in Figure 3. The 0.75 threshold lies inside the confidence interval [0, 0.882) and hence the null hypothesis is not rejected. In other words, the

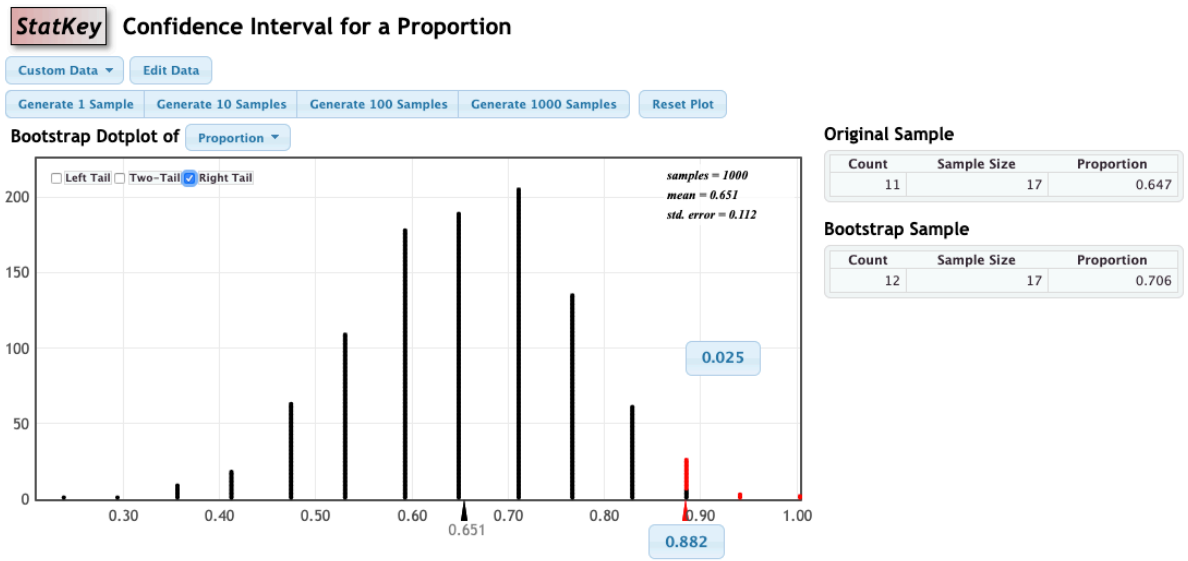

Figure 3. Bootstrap confidence interval for *Curiosity* KSO for TC module (Course section 24-TC-F17)

proportion of students performing at a satisfactory level being less than 75% is not statistically significant at the 95% confidence level.

Results of the statistical analysis for the proportions that did not meet the 75% threshold in Figure 2 are shown in Table 8. It is only for section 33-TC-F18 that the shortfall of the proportion from 75% is statistically significant at the 95% confidence level. Since the proportion for the other KSOs that fall below 75% in each course section is the same as for the *Curiosity* KSO, the statistical test for those will be identical to that for the *Curiosity* KSO.

Table 8. Results of Statistical Analysis for Assessment of KSOs for TC module

Course Section (No. of Students)	KSOs	Proportion	95% Confidence Interval	Is Shortfall Statistically Significant?
21-TC-F17 (14)	Curiosity, Value, Opportunity	0.57	[0, 0.786)	No
24-TC-F17 (17)	Curiosity, Insight, Value, Opportunity	0.65	[0, 0.882)	No
33-TC-F18 (13)	Curiosity, Contrarian, Value, Opportunity	0.31	[0, 0.538)	Yes

Assessment Results and Sample Statistical Comparisons for LFF, CoP and ET Modules

Assessments similar to those described for the *Thinking Creatively* module were also performed for the *Learning from Failure*, *Cost of Production*, and *Effective Teams* modules. The proportion of students in course sections meeting or exceeding the satisfactory threshold levels for each KSO are shown in Figures 4-6.

The results of the statistical analysis for select KSOs for the *Learning from Failure* and *Effective Teams* modules are shown in Tables 9 and 10. For the *Cost of Production* module, students in both sections had high student performances.

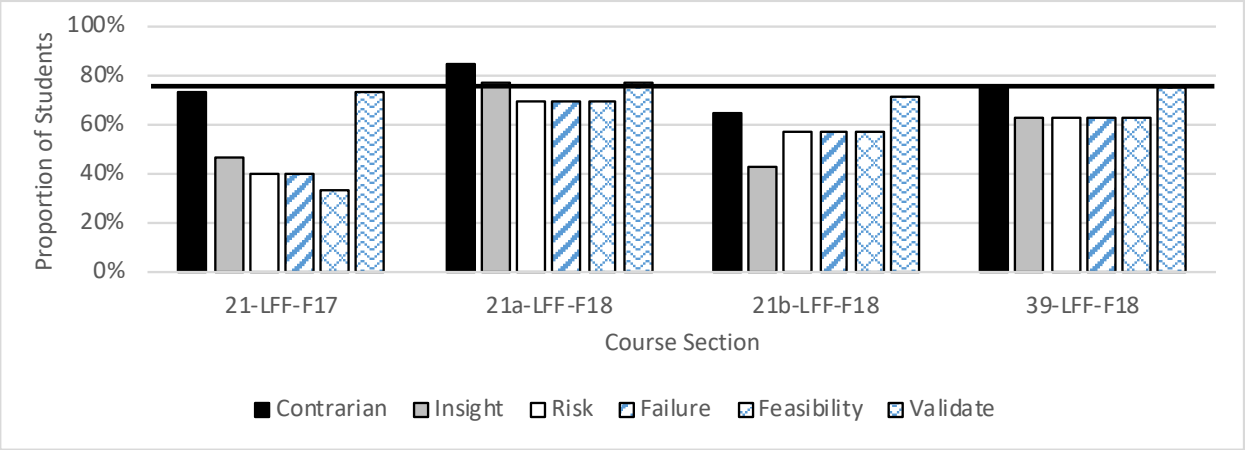

Figure 4. Proportion of students at or above KSO thresholds for LFF module

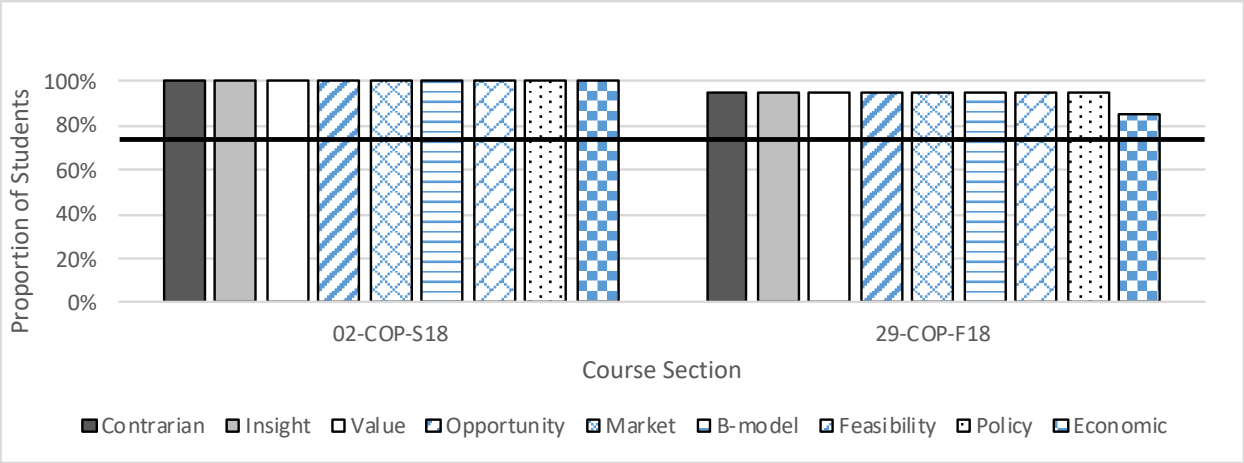

Figure 5. Proportion of students at or above KSO thresholds for CoP module

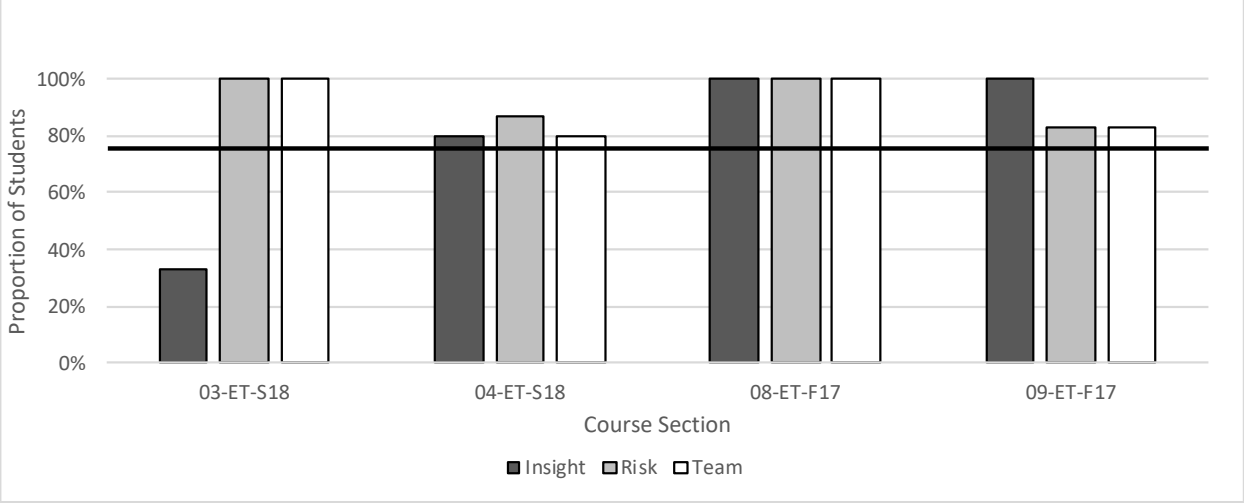

Figure 6. Proportion of students at or above KSO thresholds for ET module

Table 9. Results of Statistical Analysis for Assessment of Select KSOs for LFF module

Course Section (No. of Students)	KSOs	Proportion	95% Confidence Interval	Is Shortall Statistically Significant?
21-LFF-F17 (15)	Insight	0.47	[0, 0.733)	Yes
	Risk, Failure	0.40	[0, 0.667)	Yes
	Feasibility	0.33	[0, 0.6)	Yes
21a-LFF-F18 (13)	Risk, Failure, Feasibility	0.69	[0, 0.923)	No
21b-LFF-F18 (14)	Contrarian	0.64	[0, 0.857)	No
	Insight	0.43	[0, 0.714)	Yes
	Risk, Failure, Feasibility	0.57	[0, 0.857)	No
39-LFF-F18 (8)	Insight, Risk, Failure, Feasibility	0.63	[0, 0.875)	No

Table 10. Result of Statistical Analysis for Assessment of *Insight* KSO for ET module

Course Section (No. of Students)	KSO	Proportion	95% Confidence Interval	Is Shortfall Statistically Significant?
03-ET-S18 (6)	Insight	0.33	[0, 0.667)	Yes

The results indicate that while visually there appear to be substantial differences between some course sections (e.g., between 21-LFF-F17 and 21a-LFF-F18, or 03-ET-S18 and 04-ET-S18), these differences are not statistically significant at the 95% confidence level.

Statistical Analysis of Differences in Student Performance between Course Sections

Differences in student performance for different course sections may provide useful information about students or instructors. However, before making any conclusions, it is important to know whether the difference in student performance between two course sections is statistically significant.

The difference in the proportions between the class sections 21a-TC-F17 and 21b-TC-F17 are analyzed to demonstrate how the two-sample proportion test can be used. For both of these sections, the proportion of students who performed at a satisfactory level exceeded 75%. The hypothesis to be tested is:

> The proportion of students scoring at or above the threshold value for the same KSO from two different course sections in which the same e-learning module was deployed are the same. i.e.,
>
> H_0: $p_1 - p_2 = 0$ (Null hypothesis)
>
> H_a: $p_1 - p_2 \neq 0$ (Alternate hypothesis)

Again, a method that accounts for small class/sample sizes is necessary and we again use the bootstrap approach. The bootstrap confidence intervals for the difference in proportions can also be obtained using the StatKey software [12]. The difference in proportion is not statistically significant if the zero proportion lies within the confidence interval (i.e., we fail to reject the null hypothesis), and is statistically significant if the zero proportion lies outside the confidence interval (i.e., the null hypothesis is rejected).

For the *Curiosity* KSO, the confidence interval for the 95% confidence level for the difference in proportion for 4000 bootstrapped samples is shown in Figure 7. The zero proportion lies outside the confidence interval [0.056, 0.444] and hence the null hypothesis is rejected. In other words, the difference in the proportion of students who performed at a satisfactory level is statistically significant at the 95% confidence level. This is the same for comparisons of the *Contrarian*, *Value* and *Opportunity* KSOs.

Table 11 shows the statistical comparison results for all KSOs for the course sections 21a-TC-F17 & 21b-TC-F17 and 21b-TC-F17 & 21-TC-F18. Although the differences in proportions for the *Curiosity, Value* and *Opportunity* KSOs are very close for the two pairs of comparisons (22% and 21%), the difference is statistically significant for the first pair, but not statistically significant for the second pair. This is because the 100% proportions for the KSOs in section 21a-TC-F17 have no variance making the variance in the difference between those and the KSOs

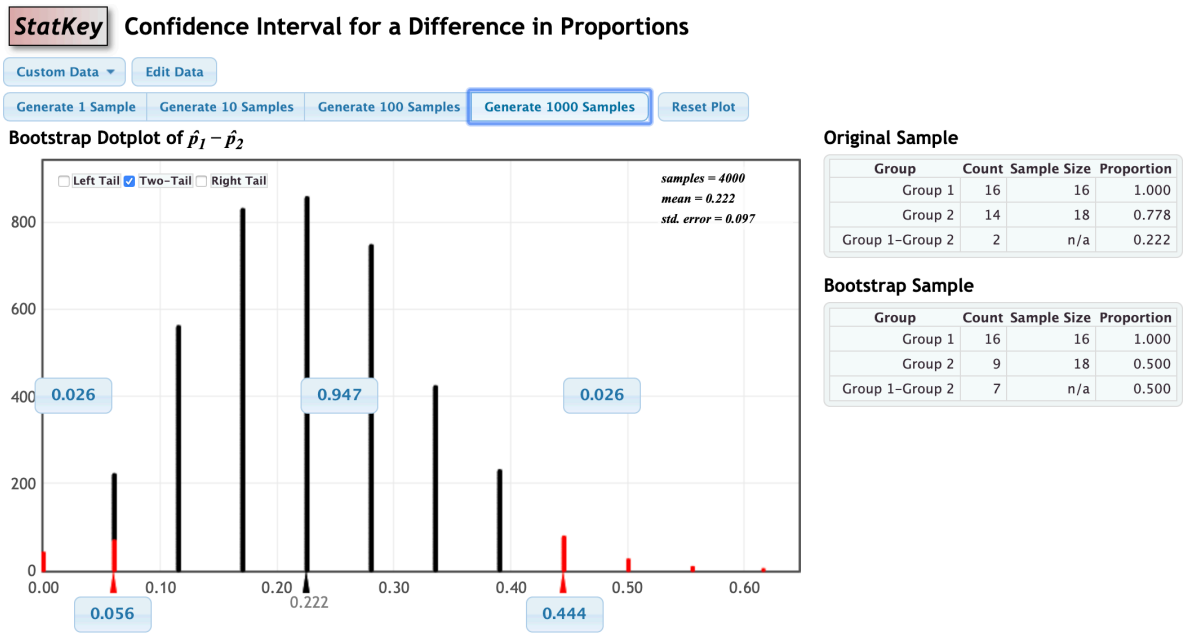

Figure 7. Bootstrap confidence interval for *Curiosity* KSO for TC module (Course sections 21a-TC-F17 & 21b-TC-F17)

Table 11. Results of Statistical Comparison Test for TC module

Course Sections (No. of Students)	KSOs	Difference in Proportion	95% Confidence Interval	Is Difference Statistically Significant?
21a-TC-F17 (18) & 21b-TC-F17 (18)	Curiosity, Contrarian, Value, Opportunity	0.22	[0.056, 0.444]	Yes
	Insight	0	–	No
21b-TC-F17 (18) & 21-TC-F18 (14)	Curiosity, Value, Opportunity	0.21	[–0.103, 0.532]	No
	Contrarian	–0.02	[–0.286, 0.278]	No
	Insight	0.21	[0.071, 0.429]	Yes

for 21b-TC-F17 smaller than the variance in the proportions between sections 21b-TC-F17 and 21-TC-F18.

Interpretation and Intervention Following Statistical Analysis

Once the statistical analysis confirms that the proportion of students performing at a satisfactory level in some course sections are not meeting the preestablished threshold, say 75%, for some KSOs, and after examining the proportions data and completing statistical comparison tests, one or more of the following actions should be pursued:

1. Dig deeper to understand cause and effect regarding student performance.
2. Have discussions with instructors to establish consistency across course sections.

3. Have discussions with instructors to help them improve their performance in integrating the e-learning modules into their courses.

First we looked at course sections taught by the same instructor. Instructor 21 taught three sections of the *Thinking Creatively* module, two in fall 2017 and one in fall 2018. However, Figure 2 shows that the proportion of students who performed satisfactorily for these three sections are quite different and the comparison test indicated that differences in the proportions are statistically significant for 21a-TC-F17 and 21b-TC-F17. The module was deployed in sections of the *Introduction to Engineering* course taken in their first semester by all first-year students. Since the instructor, e-learning module and the contextual activity were the same for these three sections, the differences can only be attributed to student performance. We investigated correlations between students' SAT scores, their overall course grade, and their GPA at the end of the first semester to see if any of these correlated with the proportions in Table 7, since it was possible that the academic ability of the students was reflected in their performance related to the e-learning module. However, there was no meaningful correlation with any of these factors. We then looked at feedback collected from students regarding their experience with the e-learning module. Two of the questions asked was regarding the time they spent to complete the module and the time they spent on the contextual activity. The time students spent on the module in average correlated reasonably well with the proportion of students who met or exceeded the thresholds. Since the student feedback was collected anonymously, direct correlations between the time that individual students spent on the module could not be correlated with their performance, so the comparison had to be done in the aggregate.

Figure 8 shows a plot of the average time students in a class spent on completing the *Thinking Creatively* module and the average of the proportion of students in that class who met or exceeded the KSO thresholds. To obtain a sufficient number of data points, results for all instructors who taught the TC module in Fall 2017 are included. In general, when students in the class spent more time on the e-learning module on average, the proportion of students meeting or exceeding the KSO thresholds increased.

Figures 1 and 2 indicate that instructor 23 gave very high ratings that resulted in all students in the class meeting or exceeding the thresholds for both AOs and KSOs. In comparison

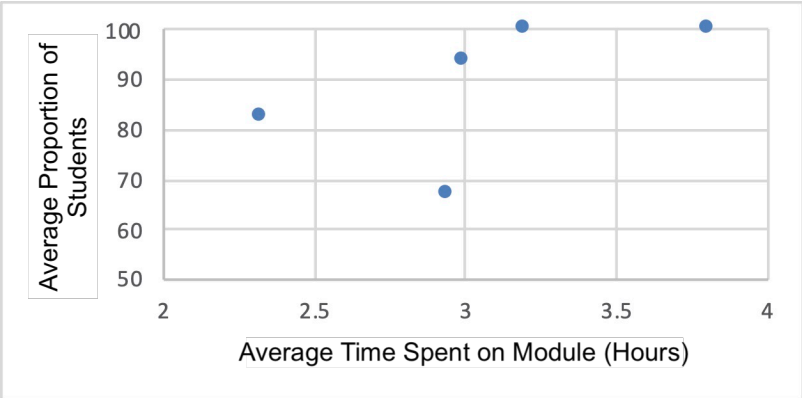

Figure 8. Correlation between average time spent on completing TC module and the average proportion of students meeting of exceeding KSO thresholds

with student performance in other course sections, we conclude that instructor 23 was too "generous" in rating students. Instructor 23 is an adjunct faculty member. Intervention is warranted to educate this instructor about effectively integrating the e-learning module and calibrating the grading with other instructors' standards.

On the other hand, Figures 1 indicates that instructor 33 did not asses AO1 or AO2, gave very low ratings for AO3 and high ratings for AO4. This instructor was new to the university, taught the course for the first time, and appears to not have effectively integrated the e-learning module into the course or performed adequate assessment. It would be appropriate to intervene with this instructor as well.

Summary

A method is proposed for assessing student achievement of the KEEN Student Outcomes (KSOs) after completing an e-learning module in a course and the related contextual activity. This is done by the instructor rating student work on assessment outcomes (AOs) related to the module and then using a weighted mapping between the AOs and KSOs to translate the ratings for AOs to ratings for KSOs. The proportion of students in a class who meet or exceed a satisfactory threshold for each KSO is used as the assessment measure. When this proportion is below a preestablished threshold (say 75%) for many KSOs, we may conclude that the class did not accomplish its goal of developing an entrepreneurial mindset in students. Results are shown for four e-learning modules deployed at the University of New Haven.

When the proportion of students who perform satisfactorily in a class for a KSO falls short of the preestablished threshold (say 75%), a bootstrap approach appropriate for small class sizes was used to determine whether this shortfall was statistically significant. Based on the results, interventions with instructors may be warranted.

The bootstrap approach was also used to determine if the difference in proportions for two course sections taught by the same instructor was statistically significant. Such differences can provide comparisons between students in classes.

Acknowledgment

The work reported herein was funded by the Kern Family Foundation. We are grateful to Professors Maria-Isabel Carnasciali, Jean Nocito-Gobel and Cheryl Li for their contributions toward mapping the Assessment Outcomes for the e-learning modules to the KEEN Student Outcomes and for coordinating the collection of assessment data from course instructors.

References

1. Kern Entrepreneurial Education Network (KEEN), "Mindset + skillset: Education in tandem," Retrieved from https://engineeringunleashed.com/Mindset-Matters/Framework.aspx, 2016.
2. S. Purzer, N. Fila, and K. Nataraja, "Evaluation of current assessment methods in engineering entrepreneurship education," *Advanced in Engineering Education*, vol. 5, no. 1, 2016.

3. M. H. Davis, J. A. Hall, and P. S. Mayer, "Developing a new measure of entrepreneurial mindset: Reliability, validity, and implications for practitioners," *Consulting Psychology Journal: Practice and Research*, 2015, Advance online publication, http://dx.doi.org/10.1037/cpb0000045
4. C. Li, R. S. Harichandran, N. O. Erdil, J. Nocito-Gobel, and M-I. Carnasciali, "Investigating the entrepreneurial mindset of engineering and computer science students," *Proceedings, ASEE Annual Conf.*, Salt Lake City, UT, Paper 21777, 2018.
5. S. Brunhaver, J. Bekki, A. R. Carberry, J. S. London, and A. F. McKenna, "Development of the engineering student entrepreneurial mindset assessment (ESEMA)," *Advances in Engineering Education*, vol. 7, no. 1, 2019.
6. R. E. Kleine III, and J-D. Yoder, "Operationalizing and assessing the entrepreneurial mindset: A rubric based approach," *Journal of Engineering Entrepreneurship*, vol. 2, no. 2, 2011, pp. 61-90.
7. J. B. Hylton, and B. Hays, "Modifying the VALUE rubrics to assess the entrepreneurial mindset," *Proceedings, ASEE Annual Conf.*, Paper 25213, 2019.
8. R. S. Harichandran, N. O. Erdil, M-I. Carnasciali, J. Nocito-Gobel, C. Li, and A. Rana, "EML indices to assess student learning through integrated e-learning modules," *Proceedings, ASEE Annual Conf.*, Tampa, FL, Paper 24668, 2019, 21 pp.
9. C. Rundel, "Chapter 8: Inference for means with small samples. Statistics 102 lecture presentation," Retrieved from <https://www2.stat.duke.edu/courses/Spring13/sta102.001/Lec/Lec8.pdf>, 2013.
10. K. Singh, and M. Xie, *Bootstrap: A statistical method*, Rutgers University, Retrieved from <http://www.stat.rutgers.edu/home/mxie/rcpapers/bootstrap.pdf>, Jan. 2020.
11. F. W. Scholz, "The bootstrap small sample properties," *Technical report BCSTECH-93-051*, Boeing Computer Services, Research and Technology, 2007.
12. R. H. Lock, P. F. Lock, K. L. Morgan, E. F. Lock, and D. F. Lock, "StatKey," Retrieved from < http://www.lock5stat.com/StatKey/bootstrap_1_cat/bootstrap_1_cat.html>, 2017.