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Direct Assessment of Entrepreneurial Minded Learning Through Integrated E-Learning Modules

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Comments

Nadiye Erdil was co-advisor on this thesis.
Jean Nocito-Gobel was a committee member.

THE UNIVERSITY OF NEW HAVEN

DIRECT ASSESSMENT OF ENTREPRENEURIAL MINDED LEARNING THROUGH INTEGRATED E-LEARNING MODULES

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ABSTRACT

Entrepreneurial Minded Learning (EML) has a significant emphasis in engineering education today. Several approaches have been used to assess the impact of various EML approaches. Many indirect assessment techniques have been used and a few direct assessment techniques have been developed. The work presented in this thesis investigates the effectiveness of two specific measurement methods to quantify entrepreneurial minded learning in students.

The University of New Haven has adopted the approach of integrating e-learning modules on entrepreneurial topics and related contextual activities into courses as the primary approach of developing an entrepreneurial mindset (EM) in students. This study focuses on 4 of the 18 modules that were deployed at the University of New Haven during the fall 2017, spring 2018 and fall 2018 semesters.

A conventional assessment technique based on the proportion of students achieving or exceeding a minimum performance threshold using instructor evaluations of learning outcomes is first investigated. By mapping the assessment outcomes for each e-learning module to KEEN Student Outcomes (KSOs) with appropriate weights, this conventional assessment approach is extended to assess student achievement of KSOs. An analysis methodology is proposed for determining whether the difference in the proportion of students at or above the threshold in two different course sections deploying the same e-learning module are statistically significant.

A recently proposed EML Index is also used to assess student achievement of KSOs through the integrated e-learning modules. An analysis methodology is also proposed for determining whether the difference in the EML Index between two course sections deploying the same e-learning module are statistically significant.

Finally, achievement of KSOs through students completing multiple integrated e-learning modules is assessed using both the conventional and EML Index approaches. The index has the advantage of being able to track the learning of each student completing multiple e-learning modules through different courses, as opposed to tracking performance in the aggregate. The index also provides a more reasonable quantification of student achievement of KSOs after completing multiple integrated e-learning modules.

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CHAPTER 1. INTRODUCTION

1.1 Problem Statement

Many different approaches have been used to develop an entrepreneurial mindset (EM) in students within a higher education context. In order to know how effective a particular approach is and whether improvements are needed, assessment of student work is necessary. Many techniques have been applied to assess student learning of entrepreneurial topics. This study investigates the use of two different assessment techniques that can be applied to assess the effectiveness of integrated e-learning modules in developing an entrepreneurial mindset in students.

1.2 Overview of Thesis

This thesis consists of six chapters and their contents are briefly described below:

1. An introduction and the research questions to be investigated are presented in Chapter 1.
2. A literature review on entrepreneurial minded learning (EML) and approaches used to assess student learning are provided in Chapter 2.
3. Direct assessment of EML by students completing integrated e-learning modules using the common approach of determining the proportion of students whose performance meets a minimum threshold is described in Chapter 3. First, student performance related to the assessment outcomes for each module are considered. Statistical analysis of the difference in the proportion between two sections of the same course in which integrated e-learning modules are deployed is analyzed to determine if student performance in these sections is statistically significant. Next, by mapping the assessment outcomes for each module to the KEEN Student Outcomes (KSOs), student achievement of KSOs is also assessed by

determining the proportion of students in a course who meet or exceed the minimum acceptable threshold for each KSO.

4. Direct assessment of EML by students completing integrated e-learning modules using the EML Index proposed by Harichandran et al. (2019) is investigated in Chapter 4. The EML Index is computed for each KSO addressed by an e-learning module. Statistical analysis of the difference in the EML Index for each KSO between two sections of the same course in which integrated e-learning modules are deployed is analyzed to determine if student performance in these sections is statistically significant.
5. Student achievement of KSOs after completing multiple integrated e-learning modules, typically in different courses, is investigated in Chapter 5.
6. Conclusions and recommendations for future work are described in Chapter 6.

1.3 Research Questions

1. Is the proportion of students who receive acceptable grades in EML assessment outcomes an effective measure of student learning of entrepreneurial concepts?

2. Can differences between classes of the proportion of students who receive acceptable grades in EML assignments be used to identify instructors' pedagogical strengths and weaknesses?

3. Can student performance in generic EML assessment outcomes be used to assess achievement of KEEN Student Outcomes (KSOs)?

4. Is the EML Index an effective measure of student achievement of KSOs?

5. Can differences in the EML Index between different classes be used to identify instructors' pedagogical strengths and weaknesses?

6. Can student achievement of KSOs in multiple courses with integrated e-learning modules be assessed?

CHAPTER 2. LITERATURE REVIEW

2.1 What is Entrepreneurial Minded Learning?

Problem solving is one of the important attributes for an individual to be successful in this modern era. The necessary training of students to face the challenges of the real world and generate solutions is the paramount input that educational institutions can make. Students require assistance to hone the outcome-oriented mindset in order to create value solutions. Furthermore, entrepreneurial skills such as habitual curiosity, self-efficacy, risk taking attitude provide an upper hand in the career making effort. In order to help students gain these entrepreneurial skills many efforts have been made to involve entrepreneurial minded learning (EML) from the very beginning of their higher education. One of the noticeable efforts is made by the Kern Entrepreneurial Engineering Network (KEEN) consisting of thousands of engineering faculty working towards the goal of helping undergraduate students of engineering curriculum to create personal, economic and societal value through entrepreneurial mindset. KEEN (2017) has developed a framework which couples engineering skills with outcomes supporting the development of an entrepreneurial mindset. The framework is based on the combined effect of the engineering and entrepreneurial skills of design, opportunity and impact which is briefly described below (https://engineeringunleashed.com/mindset-matters/framework.aspx):

I. Design: Within engineering education, design plays a common role right from developing requirements, to analyzing solutions and creating prototypes. Design still remains important but focus on only design without opportunity exploration and impact assessment may not create value. This gap is bridged by the help of the KEEN framework.

II. Opportunity: Recognition of opportunity becomes the powerful skill when coupled with engineering design. This forces students to search for market interests by knowing the customers and their needs, developing new business models and also assessing the regulatory issues.

III. Impact: For value creation identifying the impact must be coupled with engineering design and recognizing the opportunity. By doing so it helps in identifying creative solutions to ambiguous problems, evaluating technical feasibility and understanding the motivations, intentions and perspectives of the stakeholders as well as the team members.

The KEEN framework tries to develop an entrepreneurial mindset in students by making use of three key elements which are:

i. Curiosity – a constant curiosity of the changing world and providing alternative acceptable solutions to the real-world problems.

ii. Connections – Collection of information by connecting to sources and gaining insight to manage the risks related.

iii. Creating Value – Identifying the unexpected opportunities and creating value for others from them in an attempt to persist and learning from the failures faced.

The expected outcome for teaching EML is to create a mindset coupled with skillset to generate value solutions for the real-world challenges. Let us take an example of a tandem bike, which is used by KEEN to demonstrate the importance of the entrepreneurial mindset (EM). The tandem bike requires two people for it to work where one provides the power and support whereas the other provides the direction. Similarly, combining the engineering skillset with a mindset can help

in creating value with the skillset being a tool for development and the mindset guiding towards the direction for value generation.

In order to become an entrepreneurially minded engineer (Pistrui, Layer & Dietrich, 2013) certain characteristics required are:

i. Opportunity Orientation – searching to identify and solve real world problems that improve people's lives through value creation
ii. Technical Empowerment – view technology as an enabler used to solve problems and create value for customers in a dynamic and changing global marketplace
iii. Business Fundamentals – understanding the business and industry the firm is in and support the advancement of the corporate agenda
iv. Interpersonal Dynamics - clear understanding of given situations and providing projects with leadership and teamwork through good communication
v. Forward Thinking – intellectual and personal curiosity in the form of looking for "what's next" and effectively and economically applying new methods

2.2 Attributes of an Entrepreneurial Mindset

Entrepreneurial Minded Learning is not just focused on promoting small business start-ups but also helps in inculcating entrepreneurial mindset (EM) into the upcoming generation engineers. Some of the attributes that an entrepreneur has are discipline, confidence, open-mindedness, self-starter, creative, determined, passionate, risk-taking attitude, and strong work ethic. EML helps an individual to gain these attributes and make them able to start think, act and feel like an entrepreneur. The EML includes values such as 'Habitual Curiosity' which encourage students to

find different solutions to problems by changing their view about the problem (Wheadon and Duval-Couetil, 2016). In order to identify the limitless possibilities and opportunities to create value, generation of curiosity in one's mind is a basic requirement. After getting an overview to the complexities of value creation process the actual attitude of an individual for successful entrepreneurial venture is determined by knowing their self-efficacy or self-belief in themselves for carrying out the task.

In their study, Wheadon and Duval Couetil (2016) discuss how the fluency in entrepreneurial knowledge and concepts impact the affective characteristic like self-efficacy and interest for the venture creation. This self-belief will be attained if one has an attitude for risk taking which is necessary to start any venture as the results may be uncertain. The path of entrepreneurship goes through the junctions of many failures, which provide lifelong learning lessons and more understanding on how to reach goals. Any entrepreneur who has started a venture will acknowledge the risks and possible failures along the way but will not let these break motivations rather use them for moving forward. Failures might make people think that this venture was not meant for them, but it all depends on the attitude and positivity one has to get what was desired. In order to acquire this entrepreneurial attitude study of EML plays a vital role. Not everyone can be entrepreneurially minded by birth, but they can develop this mindset through entrepreneurial minded learning. EML promotes relying on effectual logic rather than the predictive logic that is commonly used by engineers (Wheadon and Duval Couetil, 2016). This effectual logic helps with knowing the means available at one's disposal for proceeding under uncertain conditions and responding to contingencies arising while creating value.

2.3 Assessment Techniques

Many institutions have developed varying programs to encourage students to develop an entrepreneurial mindset through curricular and extra-curricular activities. Assessment is required to determine the effectiveness of these approaches. Table 2.1 shows the different assessment techniques that are commonly applied to evaluate student performance related to entrepreneurial learning.

Table 2.1: Common Assessment Techniques

Assessment Technique	Summary
Indirect assessment	- Uses information obtained by surveying participants. - Used to collect opinions of the population being surveyed. - Usually reflects current views and provides the knowledge levels of the population. - Easy data collection from a large group of respondents with the validity of the data dependent on the quality of the questions. - Pre and post surveys can used to assess growth after an intervention. - Feedback surveys can be used to identify the impact of a certain deployment or knowledge session and can provide fruitful insights for future improvement.
Direct assessment	- Commonly carried out by conducting tests or exams, assignments, projects or presentations. - Assessed directly based on student performance in the given work and knowledge gained after participating in coursework.

2.3.1 Indirect Assessment via Pre and Post Survey Technique

Pre and post surveys are commonly used indirect assessment instruments. The pre survey provides a baseline of the participant skill or knowledge level before a learning experience. The post survey,

completed by the participants after the learning experience, provides data on the change on participants' perceptions as a result of the learning experience. The literature provides many examples of pre and post survey studies in engineering education as well as entrepreneurial education. Comparing student perceptions related to entrepreneurial intentions before and after taking an entrepreneurial course (Gabi et al., 2016), assessing student interest and their level of confidence in cybersecurity before and after completing a course (Bell et al., 2015), and assessing student learning through integrated e-learning modules (Erdil et al., 2017) are some examples.

2.3.2 Indirect Assessment using Feedback Surveys

Assessment based on feedback provides an understanding of what students absorbed from a learning experience. Feedback can provide insights related to the impact of a learning experience, potential for improvement (e.g., an indication of whether the depth of topics covered was suitable or not), etc. Erdil et al. (2017) used this technique to assess the impact of deploying e-learning modules in engineering courses by collecting instructor and student feedback. Dave (2014) developed an Entrepreneurial Intent Scale (EIS) based on feedback using a questionnaire to measure entrepreneurial intent targeting three specific factors required for a successful business set-up which included the creation of value in the market, practical startup and operation of the entrepreneurial venture, and creative thinking. The proposed EIS is an efficient measure of the entrepreneurial intent as it is free from the conceptual confounding of attitude and belief.

2.3.3 Direct Assessment

Another assessment technique used is based on grading tests, exams, assignments or projects provided to students. Since student performance is directly assessed by instructors, it is called

direct assessment. Direct assessment is based on actual student work, while indirect assessment is based on their perceptions; therefore the former is considered a more powerful approach.

DiBerardino et al. (2018) applied Project Based Learning (PBL) in their study to incorporate EML in their System Dynamics course which targeted the outcomes such as identifying unexpected opportunities, creating solutions to meet customer demands, identifying motivations for stakeholders, and presentation of technical information with effective written reports. They directly assessed student work to determine how well the EML outcomes were achieved.

Salib et al. (2014) used direct assessment to investigate students' motivation and intention to complete work in an entrepreneurial education setting. The change in students' mindsets was assessed by grading specific project work that required curiosity to find an optimum solution. The motivation of students was assessed by their ability to identify a topic or a problem and design of a consistent approach to meet the expected deliverables. The student's performance was graded based on weekly meetings to assess the status of the project, two dry run presentations and one final presentation.

Dancz et al. (2016) used direct assessment technique by applying a rubric to assess specific deliverables for a Grand Challenge Sustainable Entrepreneurship Projects for civil engineering students. The major components of the program were hands on research/project experience, and an interdisciplinary curriculum covering entrepreneurship, global dimension and service learning. The entrepreneurship deliverables were assessed based on how students collaborated as a team, applied critical and creative thinking to problems, constructed a customer-appropriate value proposition, persisted and learned from failure, effective project management through final

delivery process, demonstration of social responsibility and relating personal liberties to entrepreneurship.

Carnasciali et al. (2018) used rubrics to assess outcomes related to specific e-learning modules on entrepreneurial topics. Student performance on contextual activities related to each module were graded by instructors with respect to achievement of specific assessment outcomes.

There have been only a few approaches to quantify learning by using an index. Fulcher (2008) used Curiosity Index to quantify students' curiosity, which he postulated was the primary contributor to life-long learning. The Canadian council on Learning developed a Composite Learning Index (CLI) to assess lifelong learning in their communities (Saisana, 2007). Harichandran et al. (2019) directly assessed EML by computing a Module Specific EML Index to determine student achievement of KEEN Student Learning Outcomes (KSO's). They also proposed an Overall EML Index to quantify student learning of individual KSOs after completion of multiple e-learning modules.

Direct assessment can also be done using a pre and post-test that is taken before and after a learning experience. This is similar to the pre and post survey technique used in indirect assessment but uses student test scores and is therefore a direct assessment method. This technique can help determine improvement due to a learning experience.

CHAPTER 3. DIRECT ASSESSMENT USING THRESHOLD LEVEL

3.1 Proportion of Students Meeting or Exceeding Threshold Level for Assessment Outcomes

This study focuses on four modules deployed at the University of New Haven out of 18 modules that were developed through the supervision of the KEEN team[*] at the University. The four e-learning modules and their abbreviations are listed in Table 3.1.

Table 3.1: E-Learning Modules used for 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)

To evaluate student learning through direct assessment, assessment rubrics consisting of 3-5 assessment outcomes (AO) were used for each module. The assessment outcomes for the four e-learning modules considered in this study are shown in Table 3.2. The rubrics were used by instructors to evaluate student performance on contextual activities and exam questions related to each module. The performance rating provided by the instructor ranged from 1 to 5, with 1=Poor,

[*] The University of New Haven's KEEN team consists of Ronald Harichandran, Dean, Nadiye Erdil, Associate Professor of Industrial and Systems Engineering, Maria-Isabel Carnasciali, Associate Professor of Mechanical Engineering, Jean Nocito-Gobel, Professor of Civil and Environmental Engineering, and Cheryl Li, Associate Professor of Mechanical Engineering.

2=Below Average, 3=Average, 4=Above Average and 5=Outstanding. Based on these ratings for each individual student for each of the assessment outcomes, the learning for AO's were assessed by setting a minimum threshold of '3=Average' for satisfactory performance. Results for the two modules Thinking Creatively (TC) and Learning from Failure (LFF) were assessed since these modules were used in the common first-year courses for all engineering programs and the contextual activities were same across all the different course sections in which these two modules were deployed. To quantify the learning 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 from the class who met the threshold for "satisfactory" performance.

Table 3.2: Assessment Outcomes for the Four Modules

Module	**AO1**	**AO2**	**AO3**	**AO4**
Thinking creatively (TC)	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 (LFF)	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 (CoP)	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 (ET)	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

3.1.1 Thinking Creatively (TC) Module

The proportion of students who scored at or above the threshold value for the assessment outcomes in different sections of the same course that deployed the TC module is listed in Table 3.3 and shown graphically in Figure 3.1. The instructor code in Table 3.3 has the structure described below:

- The M used as the first letter indicates that the deployment belongs to a master's level institution.
- The two digits following the first letter is a numeric code assigned to each institution in a broad study. The University of New Haven was assigned the code "03".
- The two digits between the dashes is a code assigned to the instructor. If the same instructor deployed a module in multiple sections, then the letter code "a", "b", etc. is used to denote the different sections.
- The letters at the end denotes the e-learning module. In this case TC = *Thinking Creatively*.

Table 3.3 Proportion of Students at or Above the Threshold for the TC Module

Instructor	Sample Size	AO1	AO2	AO3	AO4
M03-23-TC	16	100%	100%	100%	100%
M03-24-TC	17	65%	76%	76%	65%
M03-21a-TC	16	38%	63%	100%	100%
M03-21b-TC	18	50%	67%	78%	100%
M03-22-TC	17	88%	76%	94%	94%
M03-11-TC	14	64%	64%	79%	79%
M03-33-TC	13	--	--	31%	100%

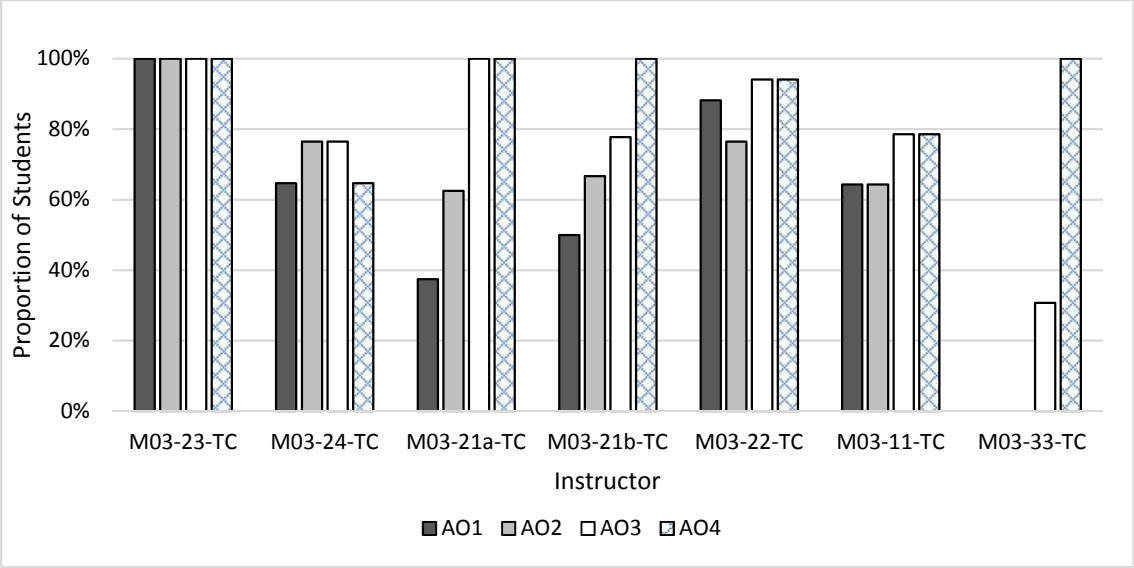

Figure 3.1: Proportion of students at or above the threshold for the TC module

While the proportions for a given assessment outcome vary significantly across different sections of the course, it is important to verify whether these differences are statistically significant. A two-sample proportion test used to investigate whether statistically significant differed exists.

3.1.1.1 Statistical Analysis

The difference in the proportions between the class sections M03-23-TC and M03-24-TC are analyzed to demonstrate how the two-sample proportion test can be used. The hypothesis to be tested is:

> The proportion of students scoring at or above the threshold value for the same assessment outcome from two different classes in which the same e-learning modules was deployed are the same. i.e.,
>
> H_O: $p_1 - p_2 = 0$ (Null hypothesis)
>
> H_a: $p_1 - p_2 \neq 0$ (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.

Looking at the data in Table 3.3, the small sample sizes do not meet the normal condition for 10 successes and 10 failures (i.e., for class M03-24-TC, no. of successes = $17 \times 0.65 = 11.05$ and no. of failures = $17 \times 0.35 = 5.95 \neq 10$). Therefore, the method for normal approximation cannot be applied for the difference in 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.

The bootstrap approach overcomes the small sample size problem by generating multiple samples that imitate the behavior of the original sample and allows us to estimate the distribution of a statistic such as the mean or the variance. In other words, computations are performed on simulated data to estimate the variation of statistics. In this study, the bootstrap is applied to estimate the variation in point estimates so as to obtain confidence intervals. The bootstrap confidence intervals for the difference in proportions are obtained using the publicly available software, StatKey (2017). 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).

3.1.1.2 Results for course sections M03-23-TC and M03-24-TC

Assessment Outcome 1 (AO1): Figure 3.2 indicates the results obtained from StatKey for the proportion of students scoring at or above the threshold limit of '3=Average' for the "Thinking Creatively" module. Using the original sample size of 16 for M03-23-TC and 17 for M03-24-TC, 4000 samples were generated in order to estimate the variation in point estimates to obtain the confidence interval at the 95% confidence level. It can be seen that the zero proportion lies outside of the confidence interval [0.118, 0.588], and therefore the null hypothesis is rejected resulting in the conclusion that the proportion of students scoring at or above the threshold value for AO1 is statistically different for the two different course sections at the 95% confidence level.

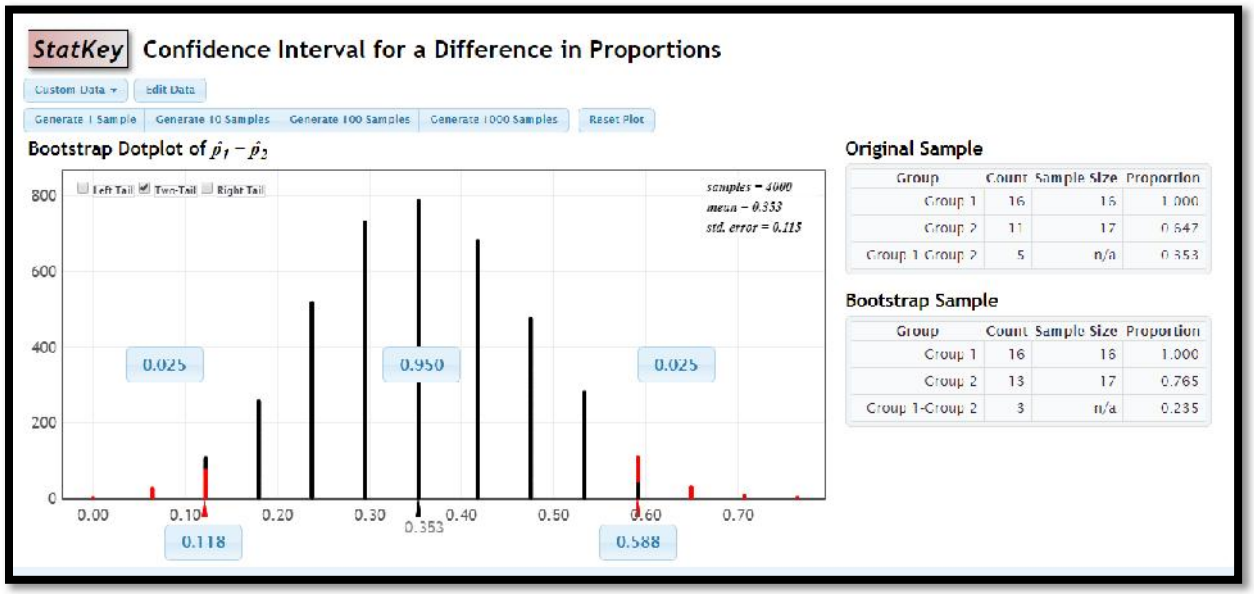

Figure 3.2: Bootstrap confidence interval for AO1 (M03-23-TC and M03-24-TC)

Assessment Outcome 4 (AO4): Similar results to AO1 are obtained for Assessment Outcome 4 (AO4), since it can be noted from Table 3.3 that proportions for both AO1 and AO4 are similar. Thus, for AO4 also the proportion of students scoring at or above the threshold value is statistically different for the two different course sections at the 95% confidence level.

Assessment Outcome 2 (AO2): Figure 3.3 shows the result from StatKey where 4000 samples were bootstrapped to estimate the variation in point estimates and the confidence interval for a 95% confidence level. The zero proportion lies outside of the confidence interval [0.059, 0.412], and hence the null hypothesis is rejected. Therefore, the proportion of students scoring at or above the threshold value for AO2 from the two different course sections is statistically different at the 95% confidence level.

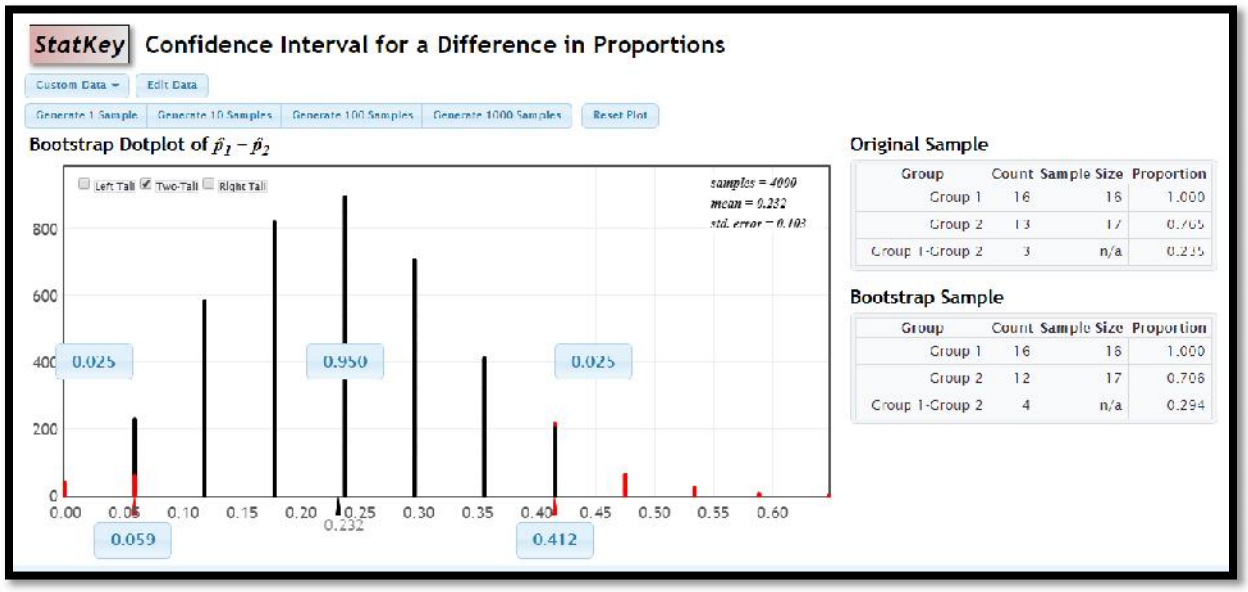

Figure 3.3: Bootstrap confidence interval for AO2 (M03-23-TC and M03-24-TC)

Assessment Outcome 3 (AO3): The proportions for AO3 are similar to those for AO2 (see Figure 3.1) and the conclusion is also similar. The proportion of students scoring at or above the threshold value for AO3 for the two different course sections are statistically different at the 95% confidence level.

3.1.1.3 Results for course sections M03-23-TC and M03-11-TC

Assessment Outcome 1 (AO1): Figure 3.4 indicates that the zero proportion lies outside the confidence interval [0.143, 0.643] obtained for 4000 samples bootstrapped using StatKey at the 95% confidence level. Thus, the null hypothesis is rejected; i.e., the proportion of students scoring at or above the threshold value for AO1 for the two different course sections are statistically different at the 95% confidence level.

Assessment Outcome 2 (AO2): The proportion of students scoring above threshold value for AO2 and A01 are similar (see Table 3.3). The conclusion for AO2 is also similar to AO1; i.e., the proportion of students scoring at or above the threshold value for AO2 for the two different course sections are statistically different at the 95% confidence level.

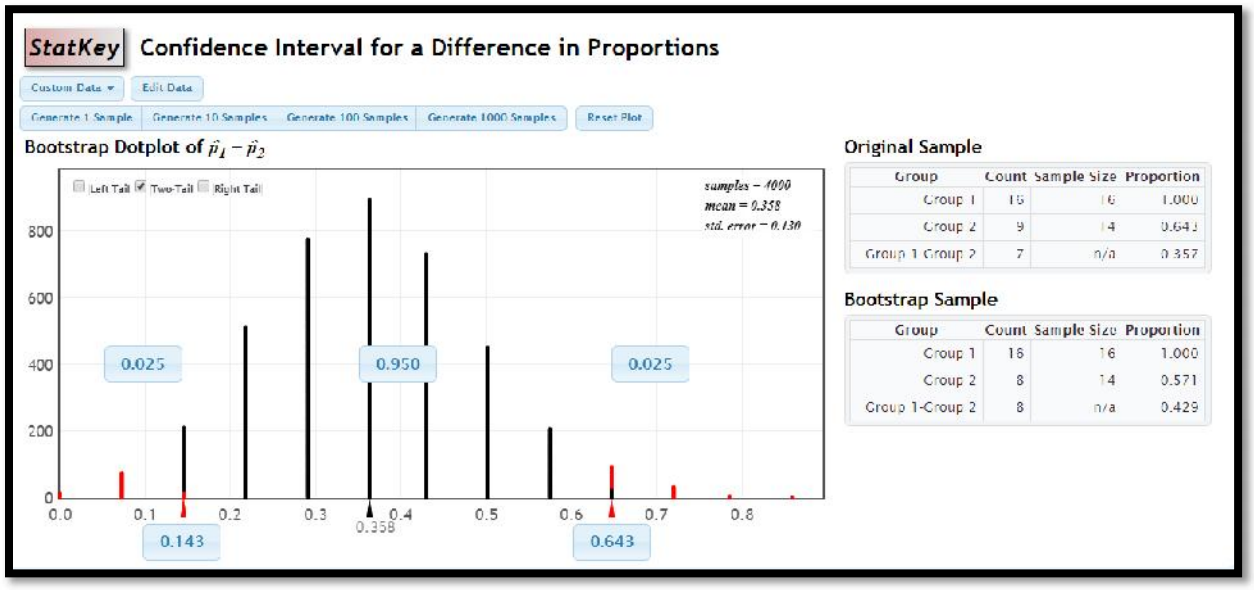

Figure 3.4: Bootstrap confidence interval for AO1 (M03-23-TC and M03-11-TC)

Assessment Outcome 3 (AO3): Figure 3.5 shows the confidence interval for 4000 samples bootstrapped using StatKey at the 95% confidence level. The zero proportion lies on the extreme lower bound of the confidence interval [0.000, 0.429; hence we fail to reject the null hypothesis. Thus, there is no significant difference in the proportion of students scoring at or above the threshold value for the two different course sections at the 95% confidence level.

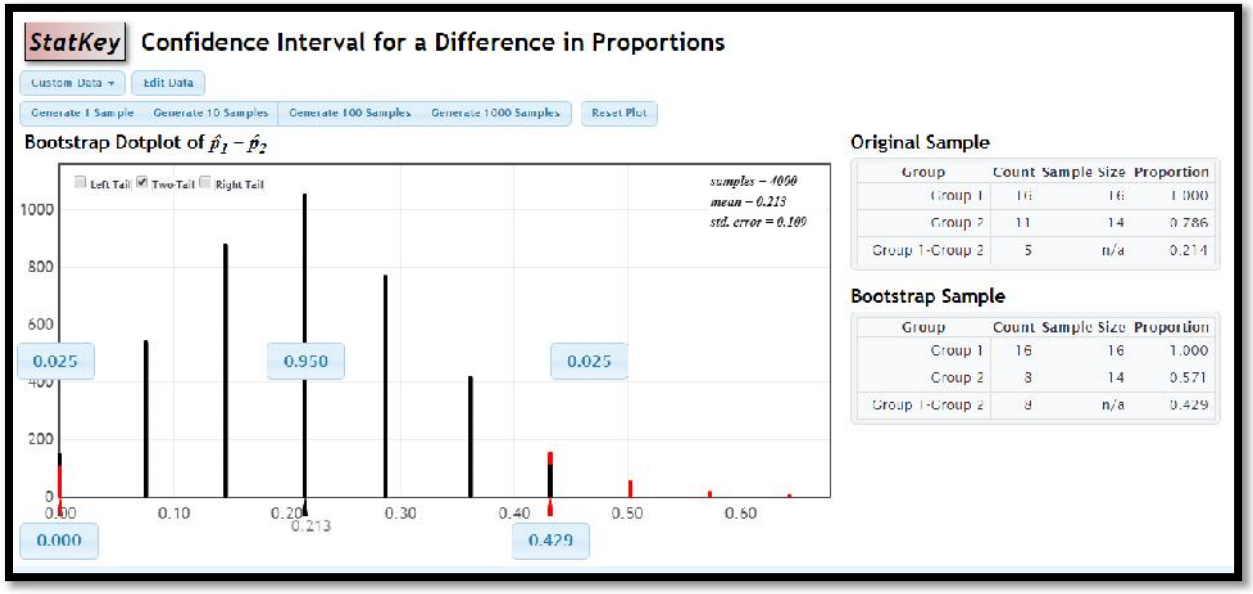

Figure 3.5: Bootstrap confidence interval for AO3 (M03-23-TC and M03-11-TC)

Assessment Outcome 4 (AO4): The proportions for A04 are similar to those for A03 (see Table 3.3) and the conclusions are also similar. There is no significant difference in the proportion of students scoring at or above the threshold value for the two different course sections at the 95% confidence level.

3.1.1.4 Results for course sections M03-21a-TC & M03-21b-TC

Assessment Outcome 1 (AO1): Figure 3.6 shows the results for 4000 samples bootstrapped using StatKey at the 95% confidence level. The zero proportion lies within the confidence interval [-0.465, 0.226] and hence we fail to reject the null hypothesis. Thus, the proportion of students scoring at or above the threshold value for the two different course sections is not statistically different for AO1.

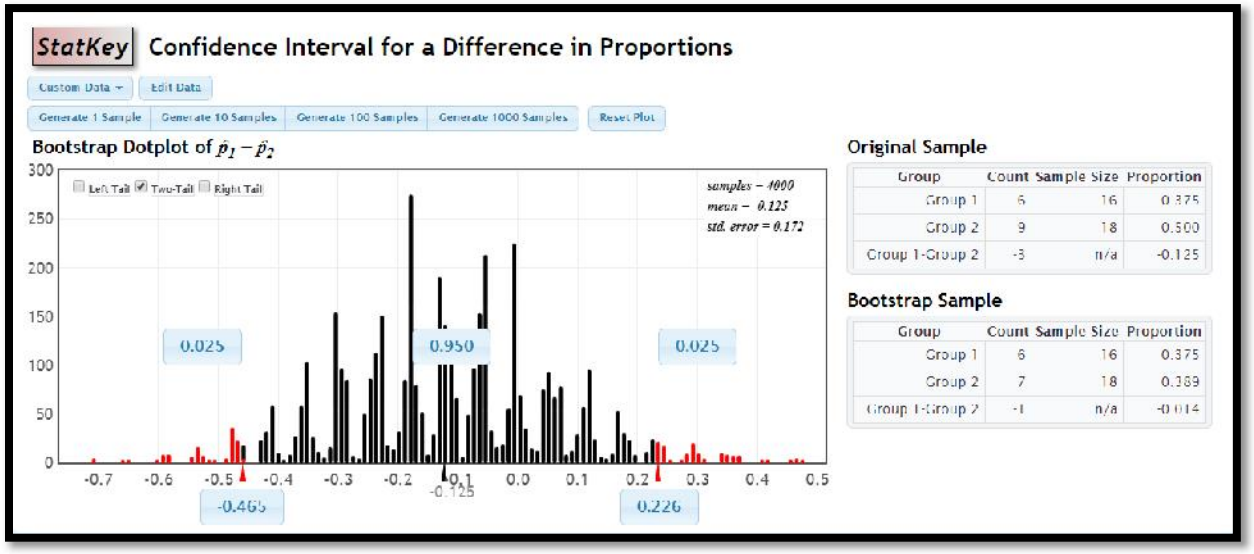

Figure 3.6: Bootstrap confidence interval for AO1 (M03-21a-TC & M03-21b-TC)

Assessment Outcome 2 (AO2): Figure 3.7 displays the result for 4000 samples bootstrapped using StatKey at the 95% confidence level. The zero proportion lies within the confidence interval [-0.347, 0.264] and hence we fail to reject the null hypothesis. Thus, the proportion of students scoring at or above the threshold value for the two different course sections is not statistically different.

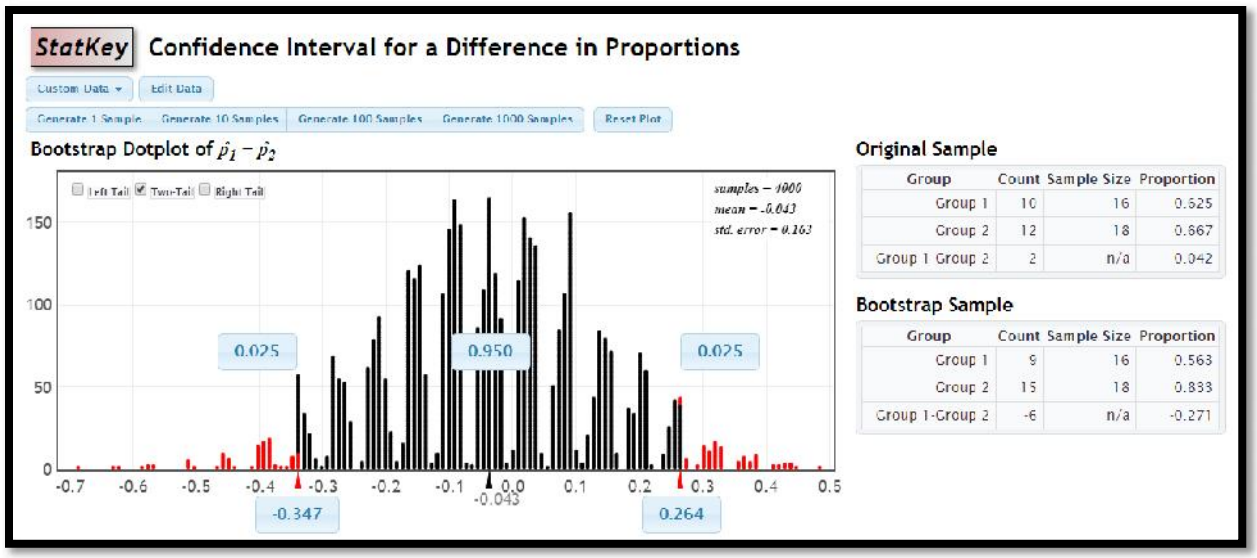

Figure 3.7: Bootstrap confidence interval for AO2 (M03-21a-TC & M03-21b-TC)

Assessment Outcome 3 (AO3): Figure 3.8 displays the result for 4000 samples bootstrapped using StatKey at the 95% confidence level. The zero proportion lies within the confidence interval [0.056, 0.444] and hence we fail to reject the null hypothesis. Thus, the proportion of students scoring at or above the threshold value for the two different course sections is not statistically different.

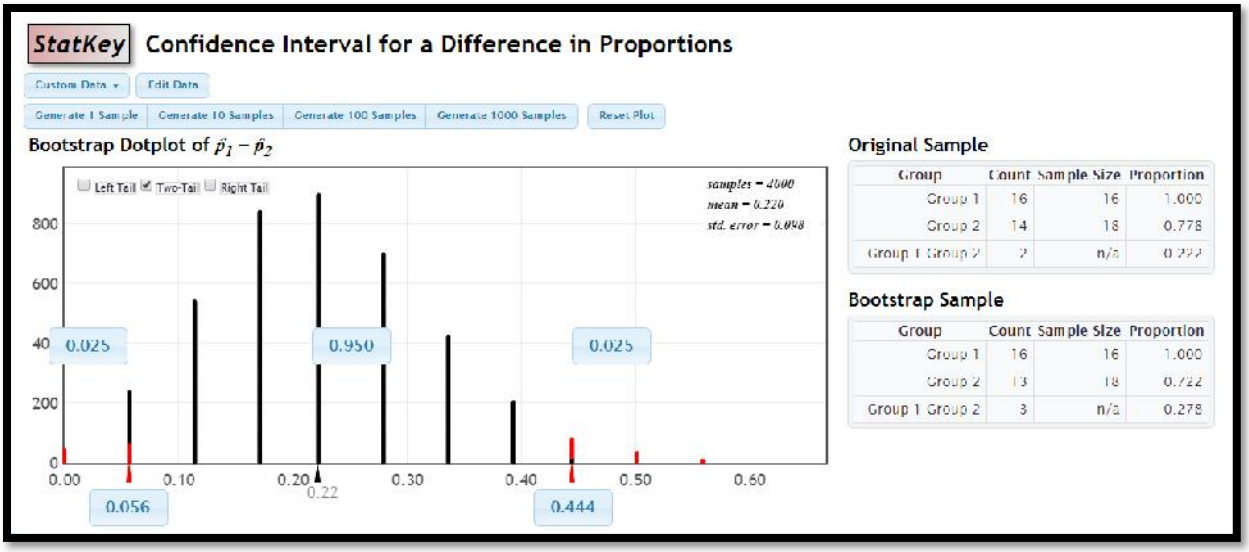

Figure 3.8: Bootstrap confidence interval for AO3 (M03-21a-TC & M03-21b-TC)

Assessment Outcome 4 (AO4): Table 3.3 shows that the proportion of students scoring above the threshold value for AO4 is 100% for the course sections M03-21a-TC and M03-21b-TC. There is no statistical difference between these proportions.

3.1.1.5 Summary of results for TC module

The results based on the confidence interval for the difference in proportion test for selected course comparisons using the bootstrapping approach is summarized in Table 3.4. The table displays the difference in the proportion of students at or above the threshold between two course section offerings, the 95% confidence interval, and whether the differences in the proportion is statistically significant for each AO.

Table 3.4: Statistical Comparison Results of Assessment Outcomes for the TC Module

Course Sections Compared	Assessment Outcome	Difference in Proportion	95% Confidence Interval	Is Difference Statistically Significant?
M03-23-TC & M03-24-TC	AO1	0.353	[0.118, 0.588]	Yes
	AO2	0.235	[0.059, 0.412]	Yes
	AO3	0.235	[0.059, 0.412]	Yes
	AO4	0.353	[0.118, 0.588]	Yes
M03-23-TC & M03-11-TC	AO1	0.357	[0.143, 0.643]	Yes
	AO2	0.357	[0.143, 0.643]	Yes
	AO3	0.214	[0, 0.429]	No
	A04	0.214	[0, 0.429]	No
M03-21a-TC & M03-21b-TC	AO1	-0.125	[-0.465, 0.226]	No
	AO2	-0.042	[-0.347, 0.264]	No
	AO3	0.222	[0.056, 0.444]	Yes
	AO4	0	---	No

Table 3.4 demonstrates why just a visual examination of the difference in proportion of students exceeding the threshold is insufficient to make conclusions. For example, the difference in proportion for AO3 and AO4 for the two course sections M03-23-TC and M03-11-TC is 21.4%, and yet this difference is not statistically significant at the 95% confidence level. On the other hand, the difference in proportion for AO3 for the course sections M03-21a-TC and M03-21b-TC is 22.2% and this difference is statistically significant at the 95% confidence level.

3.1.2 Learning from Failure (LFF) Module

The proportion of students scoring at or above the threshold value for the assessment outcomes in different sections of the same course that deployed the LFF module is listed in Table 3.5 and shown graphically in Figure 3.9.

Table 3.5: Proportion of Students at or Above the Threshold for the LFF Module

University	Instructor	AO1	AO2	AO3	AO4
UNH	M03-11-LFF	60%	73%	73%	53%
UNH	M03-21a-LFF	85%	85%	77%	85%
UNH	M03-21b-LFF	79%	64%	71%	57%
UNH	M03-39-LFF	100%	75%	75%	75%

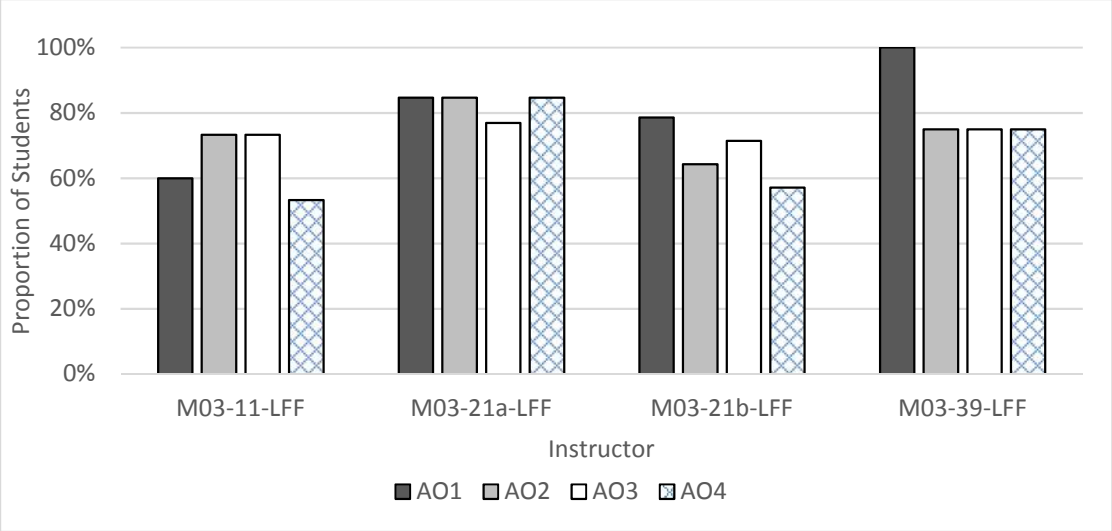

Figure 3.9: Proportion of students at or above the threshold for the LFF module

As with the TC module, statistical analysis using the bootstrap confidence interval was performed for comparing the difference in the proportion of students at or above the threshold for various pairs of course sections and the results are summarized in Table 3.6.

Table 3.6: Statistical Comparison Results of Assessment Outcomes for the LFF Module

Course Sections Compared	Assessment Outcomes	Difference in Proportion	95% Confidence Interval	Is Difference Statistically Significant?
M03-11-LFF & M03-21a-LFF	AO1	-0.246	[-0.533, 0.097]	No
	AO2	-0.113	[-0.400, 0.174]	No
	AO3	-0.036	[-0.333, 0.272]	No
	AO4	-0.313	[-0.600, 0.021]	No
M03-21a-LFF & M03-21b-LFF	AO1	0.060	[-0.236, 0.352]	No
	AO2	0.203	[-0.157, 0.500]	No
	AO3	0.055	[-0.253, 0.357]	No
	A04	0.275	[-0.033, 0.571]	No

Although the difference in the proportion of students at or above the threshold reaches 31.3% for AO4 for course sections M03-11-LFF and M03-21a-LFF, none of the differences are statistically significant at the 95% confidence level.

3.1.3 Recommended Follow-Up When Difference in Proportion is Significant

A significant difference in the proportion of students at or above the threshold between two different course sections provides sufficient reason for the course or program coordinator to determine whether the difference was caused by weaker students in the section or whether the instructor needed help in better integrating the e-learning module. If it is determined that student performance was weaker because of the instructor, then the course or program coordinator should actively take measures to help the instructor.

3.2 Proportion of Students at or Above Thresholds for KEEN Student Outcomes (KSOs)

In the previous section, assessment was carried out to identify the proportion of students at or above a certain threshold value for each assessment outcome. The assessment outcomes vary for each e-learning module. The e-learning modules were designed so that collectively they would address all 18 of the KEEN student learning outcomes (Carnasciali et.al, 2018) which are shown in Table 3.7. These 18 outcomes are henceforth referred to as the KEEN Student Outcomes (KSOs). This section addresses assessment of achieving the KSOs.

Table 3.7: 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

To know how well the content of each e-learning module addressed the KEEN Framework, the KEEN team at the University of New Haven mapped module assessment outcomes to the KSOs by assigning a depth of coverage, with 3=High, 2=Medium, 1=Low and 0=No coverage. The weights assigned to the assessment outcomes for each KSO and are shown in Table 3.8.

Table 3.8: 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	0
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															

3.2.1 Thinking Creatively (TC) Module

The weights for mapping the AOs to the KSOs are shown in Table 3.9 for the TC e-learning module. Since the acceptable threshold for each AO was 3, the threshold for each KSO was obtained by multiplying the weight for each AO by 3 and adding them together. The threshold value for each KSO covered by the TC module is shown in Table 3.9

Table 3.9: AO-KSO Mapping and Threshold Values for TC Module

KSO	AO1	AO2	AO3	AO4		Threshold Value
Curiosity	0	0	3	3		18
Contrarian	0	0	2	0		6
Insight	0	0	0	3		9
Risk	0	0	0	0		0
Value	0	0	2	2		12
Failure	0	0	0	0		0
Opportunity	0	0	2	2		12
Market	0	0	0	0		0
B_Model	0	0	0	0		0
Feasibility	0	0	0	0		0
Customer	0	0	0	0		0
Policy	0	0	0	0		0
Economic	0	0	0	0		0
Societal	0	0	0	0		0
Validate	0	0	0	0		0
Team	0	0	0	0		0
S_Chain	0	0	0	0		0
IP	0	0	0	0		0

A student's achievement score of a KSO by completing the integrated TC e-learning module can be obtained by multiplying the instructor's ratings for each of the AOs by the corresponding weight and adding them together. If the student's achievement score of a KSO is at or above the threshold

value, then the student's performance could be considered satisfactory. Since the threshold value varies from one KSO to another because the weights for the AOs are different, it is convenient to normalize the student's achievement score by dividing it by the threshold value for the KSO. The student performance will 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 mathematically through

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

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,

t = number of assessment outcomes for module m

The normalized achievement scores for each student in the course section M03-23-TC for the five KSOs covered by the TC module are shown in Table 3.10. In this course section, all students are at or above the threshold normalized achievement score of 1.0 for all five KSOs and hence the proportion of students with satisfactory performance is 100% for all five KSOs.

The proportion of students scoring at or above the threshold value for individual KSOs related to the TC module in different course sections is shown in Table 3.11. These proportions are displayed graphically in Figure 3.10.

Table 3.10: Normalized Achievement Scores for KSOs Covered by TC Module

Student	AO1	AO2	AO3	AO4	Curiosity	Contrarian	Insight	Value	Opportunity
1	4	4	4	4	1.3	1.3	1.3	1.3	1.3
2	4	4	4	5	1.5	1.3	1.7	1.5	1.5
3	4	4	4	4	1.3	1.3	1.3	1.3	1.3
4	4	3	4	4	1.3	1.3	1.3	1.3	1.3
5	4	3	4	4	1.3	1.3	1.3	1.3	1.3
6	4	5	5	5	1.7	1.7	1.7	1.7	1.7
7	4	3	3	4	1.2	1.0	1.3	1.2	1.2
8	4	3	3	3	1.0	1.0	1.0	1.0	1.0
9	4	4	4	5	1.5	1.3	1.7	1.5	1.5
10	4	3	4	3	1.2	1.3	1.0	1.2	1.2
11	4	3	4	4	1.3	1.3	1.3	1.3	1.3
12	3	3	3	3	1.0	1.0	1.0	1.0	1.0
13	4	4	4	4	1.3	1.3	1.3	1.3	1.3
14	3	4	4	3	1.2	1.3	1.0	1.2	1.2
15	4	4	4	5	1.5	1.3	1.7	1.5	1.5
16	3	4	4	4	1.3	1.3	1.3	1.3	1.3
Proportion of students with normalized scores ≥ 1					100%	100%	100%	100%	100%

Table 3.11: Proportion of Students at or Above KSO Thresholds for TC Module

KSOs	M03-23-TC	M03-24-TC	M03-21a-TC	M03-21b-TC	M03-22-TC	M03-11-TC	M03-33-TC
Curiosity	100%	65%	100%	78%	94%	57%	31%
Contrarian	100%	76%	100%	78%	94%	79%	31%
Insight	100%	65%	100%	100%	94%	79%	100%
Value	100%	65%	100%	78%	94%	57%	31%
Opportunity	100%	65%	100%	78%	94%	57%	31%

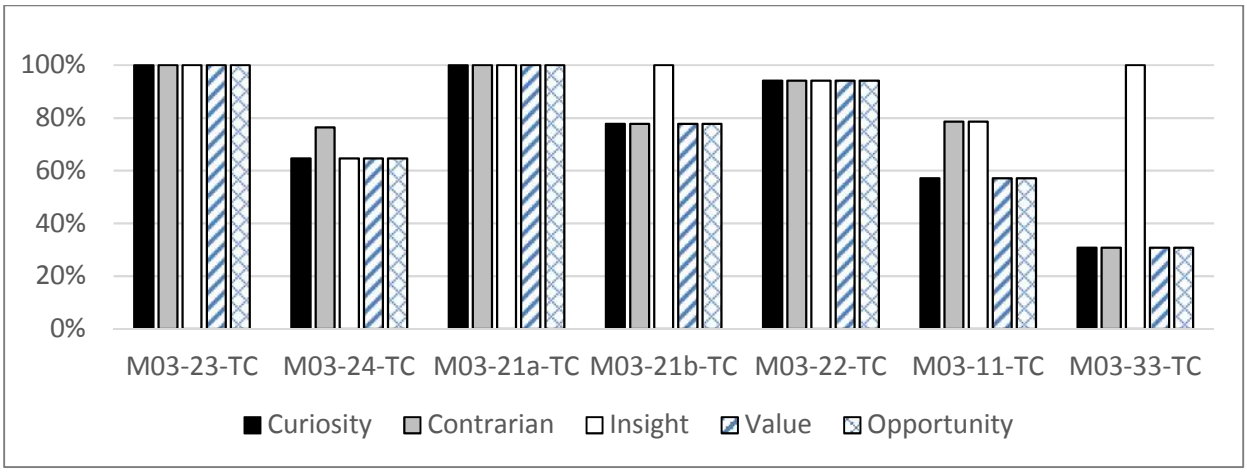

Figure 3.10: Proportion of students at or above KSO thresholds for TC module

3.2.1.1 Statistical analysis of difference in proportion for course sections M03-23-TC and M03-24-TC

The same bootstrap confidence interval of the proportion of students at or above the threshold for AOs was used to perform the statistical analysis for the proportion of students at or above exceeding the threshold for KSOs. For example, 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 3.11. The zero proportion lies outside the confidence interval [0.118, 0.588] and hence the null hypothesis is rejected. In other words, the difference in the proportion of students at or above the threshold is statistically significant at the 95% confidence level.

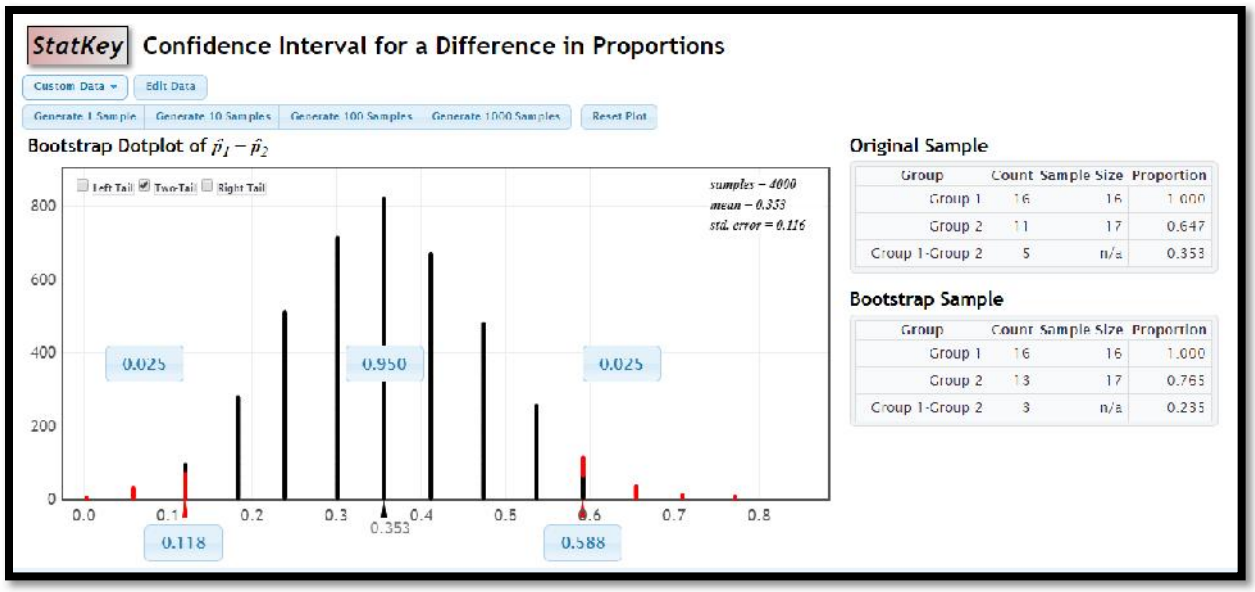

Figure 3.11: Bootstrap confidence interval for *Curiosity* KSO for TC module (M03-23-TC & M03-24-TC)

3.2.1.2 Summary of results for assessment of KSOs for TC module

The results of the statistical analysis for comparing the differences in the proportion of students at or above the KSO threshold for two pairs of course sections are shown in Table 3.12. In comparing the results with those in Table 3.4 for the difference in proportion for AOs, the following observations can be made:

- For course sections M03-23-TC and M03-24-TC, the difference in the proportion of students exceeding the AO threshold was statistically different for all four AOs at the 95% confidence level. Correspondingly, the difference in the proportion of students exceeding the KSO threshold was statistically different for all five KSOs at the 95% confidence level.

- For course sections M03-21a-TC and M03-21b-TC, the difference in the proportion of students exceeding the AO threshold was statistically different for two of the four AOs at the 95% confidence level. However, the difference in the proportion of students exceeding

the KSO threshold was statistically different for all five KSOs at the 95% confidence level. The reason for this is that the two AOs for which the difference in proportion was statistically different did not map into any of the five KSOs.

Table 3.12: Results of Statistical Comparison Analysis for Assessment of KSOs for TC module

Course Sections Compared	KSO	Difference in Proportion	95% Confidence Interval	Is Difference Statistically Significant?
M03-23-TC & M03-24-TC	Curiosity	0.353	[0.118, 0.588]	Yes
	Contrarian	0.235	[0.059, 0.471]	Yes
	Insight	0.353	[0.118, 0.588]	Yes
	Value	0.353	[0.118, 0.588]	Yes
	Opportunity	0.353	[0.118, 0.588]	Yes
M03-21a-TC & M03-21b-TC	Curiosity	0.222	[0.056, 0.444]	Yes
	Contrarian	0.222	[0.056, 0.444]	Yes
	Insight	0	--	No
	Value	0.222	[0.056, 0.444]	Yes
	Opportunity	0.222	[0.056, 0.444]	Yes

3.2.2 Learning from Failure (LFF) Module

The proportion of students scoring above the threshold value for individual KSOs related to LFF the module in different course sections is shown in Table 3.13.

Table 3.13: Proportion of Students at or Above KSO Thresholds for LFF Module

KSO	M03-11-LFF	M03-21a-LFF	M03-21b-LFF	M03-39-LFF
Contrarian	73%	85%	64%	75%
Insight	47%	77%	43%	63%
Risk	40%	69%	57%	63%
Failure	40%	69%	57%	63%
Feasibility	33%	69%	57%	63%
Validate	73%	77%	71%	75%

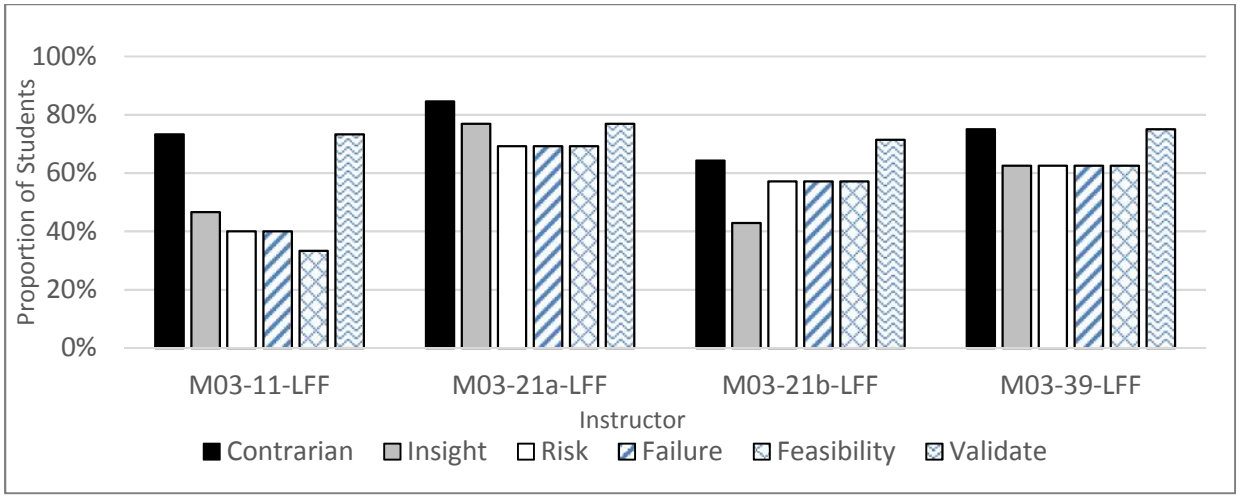

Figure 3.12: Proportion of Students at or Above KSO Thresholds for LFF Module

3.2.2.1 Summary of results for assessment of KSOs for LFF module

The results of the statistical analysis for comparing the differences in the proportion of students meeting or exceeding the KSO threshold for two pairs of course sections are shown in Table 3.14 In comparing the results with those in Table 3.6 for the difference in proportion for AOs, the following observations can be made:

- For course sections M03-11-LFF and M03-21a-LFF, the difference in the proportion of students exceeding the AO threshold had no statistical difference for all four AOs at the

95% confidence level. Correspondingly, the difference in the proportion of students exceeding the KSO threshold has no statistical difference for all five KSOs at the 95% confidence level.

- For course sections M03-21a-LFF and M03-21b-LFF, the difference in the proportion of students exceeding the AO threshold has no statistical difference for two of the four AOs at the 95% confidence level. Correspondingly, the difference in the proportion of students exceeding the KSO threshold has no statistical difference for all five KSOs at the 95% confidence level.

Table 3.14: Results of Statistical Comparison Analysis for Assessment of KSOs for LFF module

Course Sections Compared	KSO	Difference in Proportion	95% Confidence Interval	Is Difference Statistically Significant?
M03-11-LFF & M03-21a-LFF	Contrarian	-0.113	[-0.400, 0.174]	No
	Insight	-0.303	[0.646, 0.051]	No
	Risk	-0.292	[-0.646, 0.072]	No
	Failure	-0.292	[-0.646, 0.072]	No
	Feasibility	-0.359	[-0.713, 0.0051]	No
	Validate	-0.036	[-0.333, 0.318]	No
M03-21a-LFF & M03-21b-LFF	Contrarian	0.203	[-0.157, 0.500]	No
	Insight	0.341	[-0.027, 0.643]	No
	Risk	0.121	[-0.247, 0.489]	No
	Failure	0.121	[-0.247, 0.489]	No
	Feasibility	0.121	[-0.247, 0.489]	No
	Validate	0.055	[-0.308, 0.382]	No

3.2.3 Cost of Production (CoP) Module

The proportion of students scoring at or above the threshold value for individual KSOs related to the CoP module in different course sections is listed in Table 3.15 and a graphical display is presented in Figure 3.13.

Table 3.15: Proportion of Student at or Above KSO Thresholds for CoP Module

KSO	M03-02-COP	M03-29-COP
Contrarian	100%	95%
Insight	100%	95%
Value	100%	95%
Opportunity	100%	95%
Market	100%	95%
B-model	100%	95%
Feasibility	100%	95%
Policy	100%	95%
Economic	100%	85%

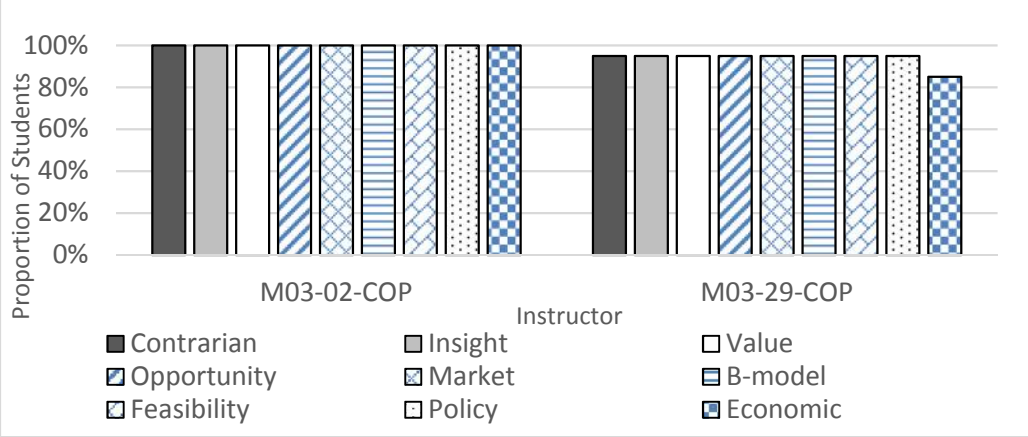

Figure 3.13: Proportion of student at or above KSO thresholds for CoP module

3.2.3.1 Summary of results for assessment of KSOs for CoP module

The results of the statistical analysis for comparing the differences in the proportion of students at or above the KSO thresholds for two pairs of course sections are shown in Table 3.16.

Table 3.16: Results of Statistical Comparison Analysis for Assessment of KSOs for CoP Module

Course Sections Compared	KSO	Difference in Proportion	95% Confidence Interval	Is Difference Statistically Significant?
M03-02-CoP & M03-29-CoP	Contrarian	0.050	[0.000, 0.150]	No
	Insight	0.050	[0.000, 0.150]	No
	Value	0.050	[0.000, 0.150]	No
	Opportunity	0.050	[0.000, 0.150]	No
	Market	0.050	[0.000, 0.150]	No
	B_Model	0.050	[0.000, 0.150]	No
	Feasibility	0.050	[0.000, 0.150]	No
	Policy	0.050	[0.000, 0.150]	No
	Economic	0.150	[0.000, 0.350]	No

3.2.4 Effective Teams (ET) Module

The proportion of students scoring at or above the threshold value for individual KSOs related to the ET module in different course sections is shown in Table 3.17 and displayed in graphically in Figure 3.14.

Table 3.17: Proportion of Students at or Above KSO Thresholds for ET Module

KSO	**M03-03-ET**	**M03-04-ET**	**M03-08-ET**	**M03-09-ET**
Insight	33%	80%	100%	100%
Risk	100%	87%	100%	83%
Team	100%	80%	100%	83%

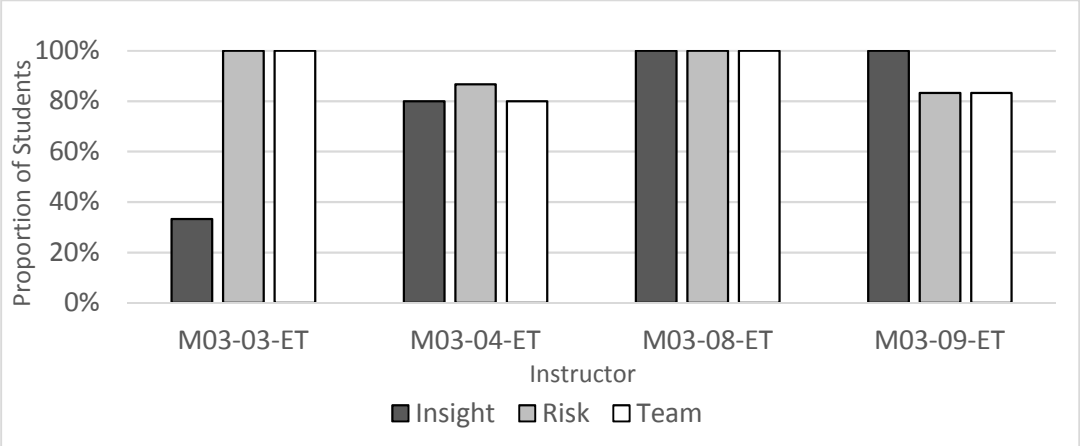

Figure 3.14: Proportion of students at or above KSO thresholds for ET Module

3.2.4.1 Summary of results for assessment of KSOs for ET module

The results of the statistical analysis for comparing the difference in the proportion of students at or above the KSO thresholds for two pairs of course sections are shown in Table 3.18. From the results the following conclusions can be made:

- For course sections M03-03-ET and M03-04-ET, the difference in the proportion of students at or above the KSO thresholds has no statistical difference for all three KSOs at the 95% confidence level even though for the *Insight* KSO, the difference is 46.7%.

- Similarly, for course sections M03-040ET and M03-08-ET, the difference in the proportion of students at or above the KSO threshold has no statistical difference for all three KSOs at the 95% confidence level.

Table 3.18: Results of Statistical Analysis for Assessment of KSOs for ET module

Course Sections Compared	KSO	Difference in Proportion	95% Confidence Interval	Is Difference Statistically Significant?
M03-03-ET & M03-04-ET	Insight	–0.467	[–0.867, 0.000]	No
	Risk	0.133	[0.000, 0.333]	No
	Team	0.200	[0.000, 0.400]	No
M03-04-ET & M03-08-ET	Insight	–0.200	[–0.400, 0.000]	No
	Risk	–0.133	[–0.333, 0.000]	No
	Team	–0.200	[–0.400, 0.000]	No

CHAPTER 4. DIRECT ASSESSMENT USING THE EML INDEX

4.1 Definition of the Module Specific Course EML Index

Harichandran et al. (2019) proposed the following Module Specific EML Index which quantifies how well on average students in a course attain each KSO after completing a given e-learning module:

$$I_{k,m} = 100 \sum_{n=1}^{s} \sum_{q=1}^{t} \frac{w_{k,q,m} a_{n,q,m}}{15 s t_{w \neq 0}} \tag{4-1}$$

where $w_{k,q,m}$ = weight assigned to KSO k for assessment outcome q in module m,

$a_{n,q,m}$ = assessment rating assigned by the instructor to student n for assessment outcome q in module m,

s = number of students assessed in the class,

t = number of assessment outcomes in module m,

$t_{w \neq 0}$ = number of assessment outcomes for KSO k in module m that have non-zero weights,

and k = 1,…,18 (KSOs) and m = 1,…,18 (e-learning modules).

In order to avoid the impact of the assessment outcomes for module m that are not related to KSO k, only the assessment outcomes that have non-zero weights are used for calculating the $I_{k,m}$. The number 15 in the denominator of Eq. 4-1 is the maximum weight of 3 multiplied by the maximum student rating of 5. Since this index is an average for the course, it is henceforth referred to as the Module Specific Course EML Index.

The maximum possible value of the Module Specific Course EML Index for KSO *k* is obtained when all students receive a maximum assessment rating of 5 for all module AOs. i.e.,

$$I_{k,m,m} = 100 \sum_{q=1}^{t} \frac{w_{k,q,m}}{3t_{w\neq 0}} \quad (4\text{-}2)$$

The Module Specific Course EML Index values computed using Eq. 4-1 for the 4 modules deployed at the University of New Haven discussed in this study are shown in the following graphical representations.

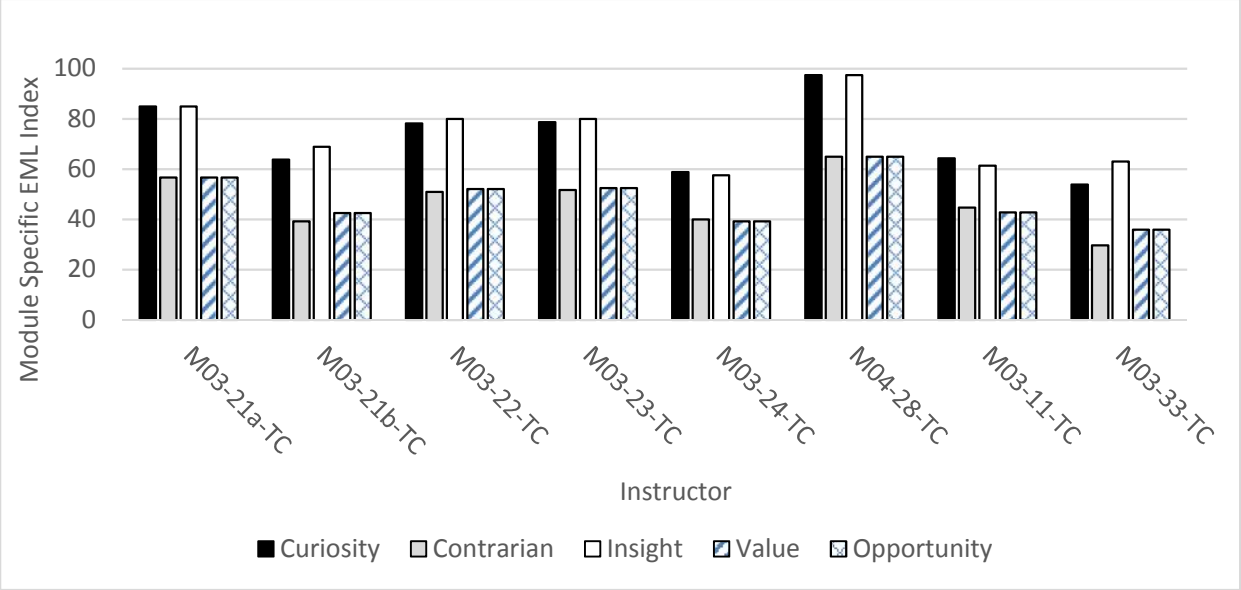

Figure 4.1: Module Specific Course EML Index for deployments of *Thinking Creatively*

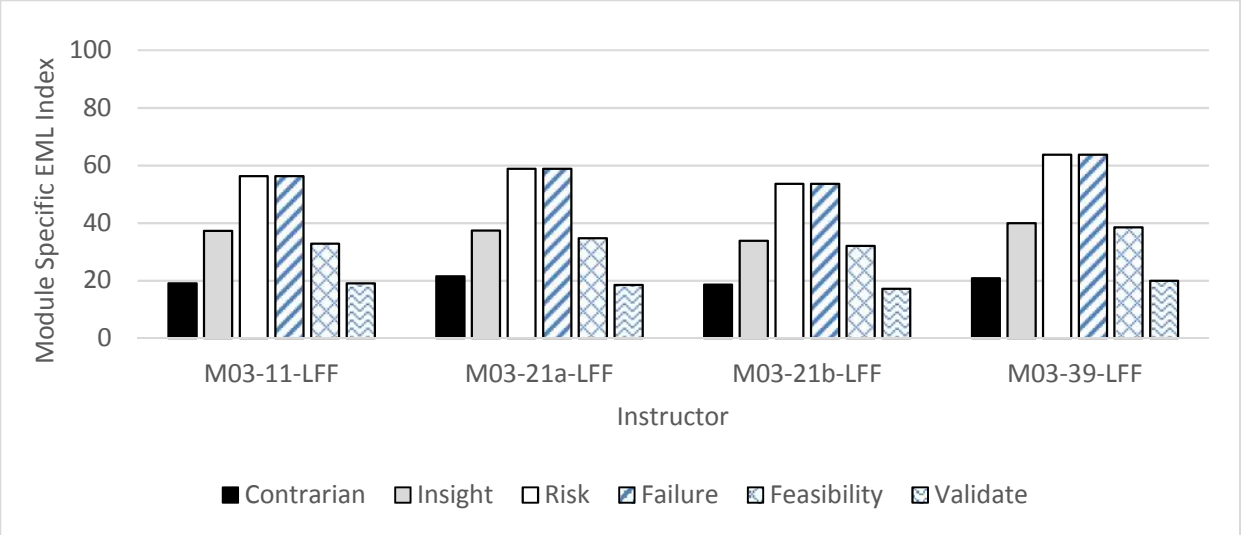

Figure 4.2: Module Specific Course EML Index for deployments of *Learning from Failure*

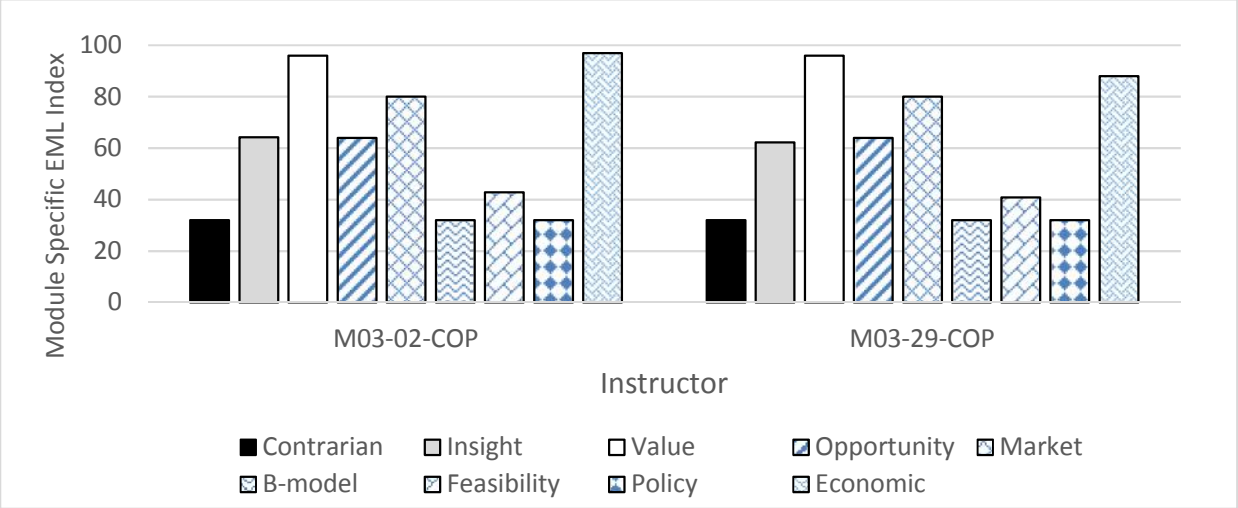

Figure 4.3: Module Specific Course EML Index for deployments of *Cost of Production*

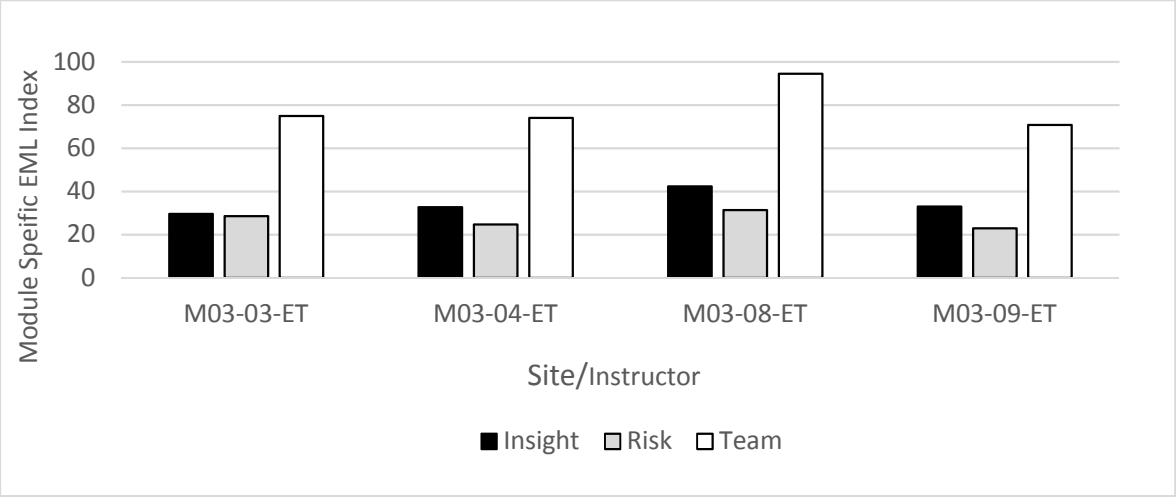

Figure 4.4: Module Specific Course EML Index for deployments of *Effective Teams*

4.1.1 Thinking Creatively (TC) Module

The Module Specific Course EML Index for the course section M03-23-TC is calculated using Eq. 4-1 and is displayed in Table 4.1. The values shown for each student are computed without the averaging over students implied in Eq. 4-1; i.e., the Module Specific Student EML Index for student *n* is given by

$$I_{n,k,m} = 100 \sum_{q=1}^{t} \frac{w_{k,q,m} a_{n,q,m}}{15 t_{w \neq 0}} \tag{4-3}$$

Table 4.1: Module Specific Student EML Index Values for KSOs covered by TC Module

Student	Assessment Outcome				KSO				
	AO1	AO2	AO3	AO4	Curiosity	Contrarian	Insight	Value	Opportunity
1	4	4	4	4	80	53	80	53	53
2	4	4	4	5	90	53	100	60	60
3	4	4	4	4	80	53	80	53	53
4	4	3	4	4	80	53	80	53	53
5	4	3	4	4	80	53	80	53	53
6	4	5	5	5	100	67	100	67	67
7	4	3	3	4	70	40	80	47	47
8	4	3	3	3	60	40	60	40	40
9	4	4	4	5	90	53	100	60	60
10	4	3	4	3	70	53	60	47	47
11	4	3	4	4	80	53	80	53	53
12	3	3	3	3	60	40	60	40	40
13	4	4	4	4	80	53	80	53	53
14	3	4	4	3	70	53	60	47	47
15	4	4	4	5	90	53	100	60	60
16	3	4	4	4	80	53	80	53	53
Module Specific Course EML Index (Average)					78.75	51.67	80.00	52.50	52.50

4.1.1.1 Statistical analysis of difference in EML Index for course sections M03-23-TC and M03-24-TC

The instructor ratings for the assessment outcomes related to each e-learning module are on an ordinal scale (1, 2, 3, 4 or 5). When these are transformed to the Student EML Index for each KSO by multiplying by weights and summing, the result remains ordinal. If the Student EML Index (given by Eq. 4-3) in different course sections are normally distributed and have similar variances, then a one-way ANOVA test can be used to determine if the means are statistically the same or different. So first we check to see if the EML Index data is normally distributed.

The results for the normality plot of the course section M03-23-TC for the *Curiosity* KSO is shown in Figure 4.5. If the data points lie close to the straight line, then the data is approximately normally distributed. In this case, the data is discrete because the instructor ratings for the AOs are discrete (i.e., 1, 2, 3, 4 or 5). The number of discrete intervals depends on how many AOs map to a particular KSO and the distribution of the ratings given by the instructor. Only two AOs map to the *Curiosity* KSO for the TC module. Despite the discrete nature of the data, it is approximately normally distributed.

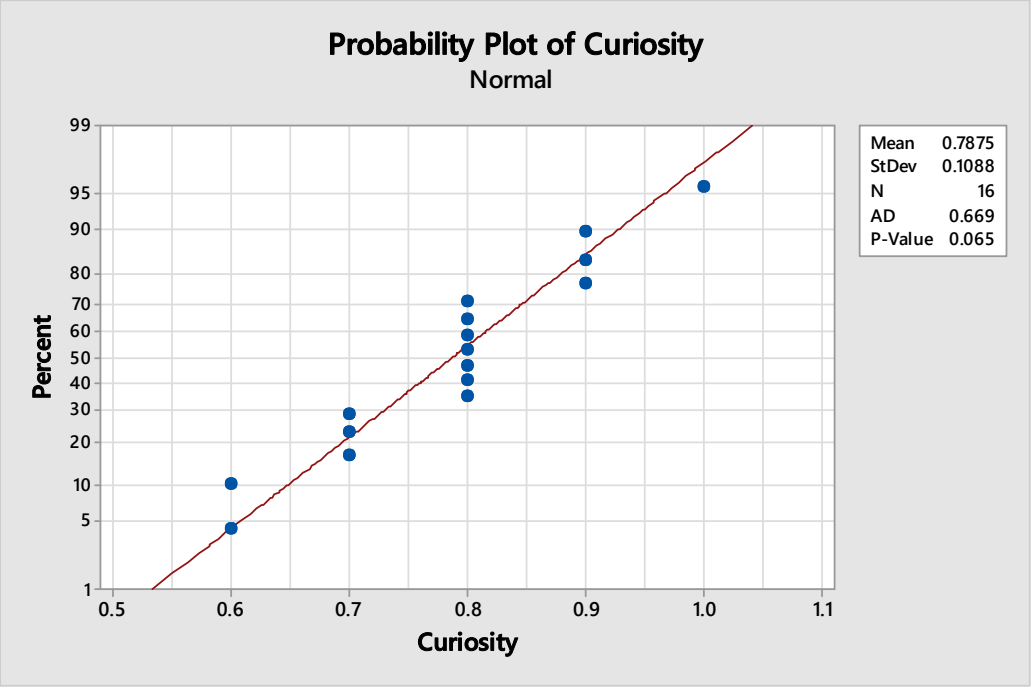

Figure 4.5: Normality plot of *Curiosity* KSO for TC module (M03-23-TC)

Figure 4.6,Figure 4.7 and Figure 4.8 show typical normality plots for the LFF, CoP and ET modules. These data are even more discrete than for the TC module and depart significantly from the normal. Therefore, in general, the one-way ANOVA is not the appropriate test to compare

differences in the Course EML Index between different course sections that deploy the same e-learning module and a non-parametric test such as the Mann-Whitney test that does not require the data to be normally distributed is more appropriate. The requirements for the Mann-Whitney test are the following:

1. The samples in each group are random.
2. The samples in one group are mutually independent of the samples in the other; i.e., there are no students who are in both course sections.
3. An ordinal measurement scale is assumed.

All of the above requirements are met by the data collected for each course.

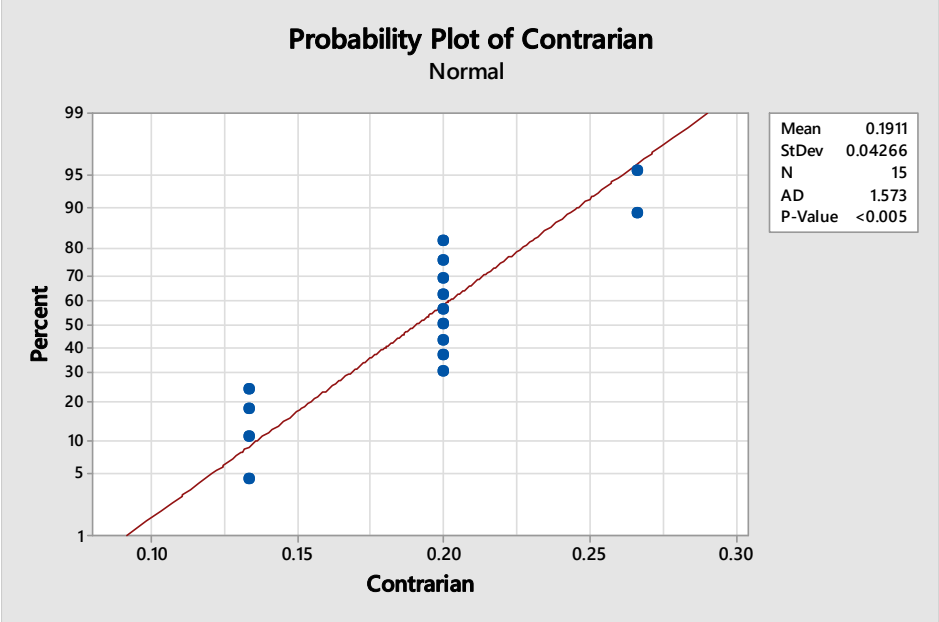

Figure 4.6: Normality plot of *Contrarian* KSO for *LFF Module* (M03-11-LFF)

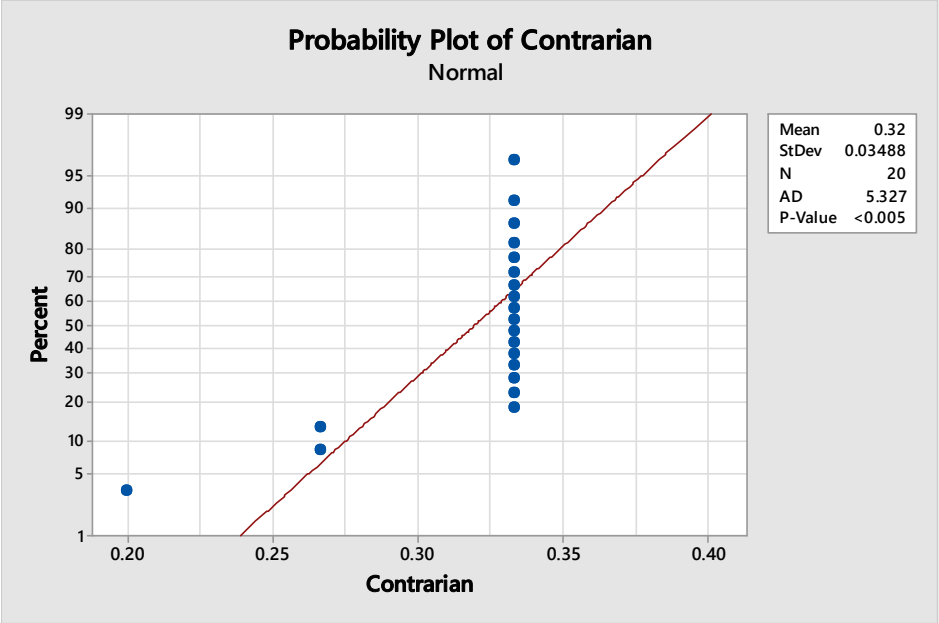

Figure 4.7: Normality plot of *Contrarian* KSO for *CoP Module* (M03-02-CoP)

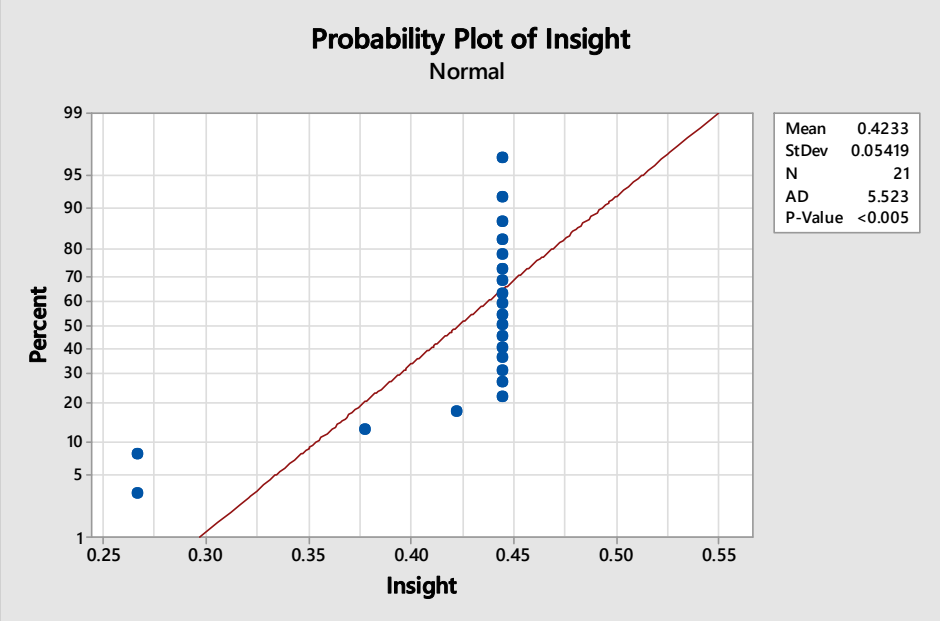

Figure 4.8: Normality plot of *Insight* for *ET* module (M03-08-ET)

The Mann-Whitney test compares the medians of the two groups rather than the means. The Course EML Index defined by Eq. 4-1 is the average for the course section, so technically, the Mann-Whitney test is not comparing the Course EML Index for two course sections, but rather the

median of the Student EML Index defined by Eq. 4-3. However, quite often the median and the mean will likely be rather similar.

4.1.1.2 Statistical analysis of difference in the EML Index for course sections M03-23-TC and M03-24-TC

The results of the Mann-Whitney test conducted for sections M03-23-TC and M03-24-TC for the *Curiosity* KSO using MINITAB are shown in Figure 4.9. The output indicates that the *p*-value is 0.0065, which is smaller than the significance level of 0.05 (i.e., confidence level of 95%), and therefore the null hypothesis is rejected. Thus, there is a significant difference in the median Student EML Index for class sections M03-23-TC and M03-24-TC. The medians for the two sections are 0.8 and 0.6, while the means (i.e., the Course EML Index) are 78.75 and 58.82. The difference in the medians is 0.2, while the difference in the means is 19.9. Therefore, it is reasonable to assume that both the difference in the medians and the difference in the means are both significant at the 95% confidence level.

```
            N  Median
M03-23-TC  16  0.8000
M03-24-TC  17  0.6000


Point estimate for η1 - η2 is 0.2000
95.0 Percent CI for η1 - η2 is (0.0999,0.3001)
W = 348.0
Test of η1 = η2 vs η1 ≠ η2 is significant at 0.0065
The test is significant at 0.0056 (adjusted for ties)
```

Figure 4.9: Mann-Whitney test results for *Curiosity* KSO
for M03-23-TC & M03-24-TC

4.1.1.3 Summary of results for TC module and comparison with results using proportions

The statistical comparison results using the Mann-Whitney test for all KSOs for two pairs of course sections are shown in Table 4.2. The results indicate that the differences in the median Student EML Index is statistically significant for all KSOs at the 95% confidence level. These results are in agreement with the difference in the proportion of students at or above the KSO threshold being statistically significant for all five KSOs at the 95% confidence level (see Table 3.12).

Table 4.2: Statistical Comparison Results of EML Index for TC Module

Course Sections Compared	KSO	Difference in Course (Mean) EML Index	Difference in Median Student EML Index	*p*-Value	Is Difference Statistically Significant?
M03-23-TC & M03-24-TC	Curiosity	19.9	20.0	0.006	Yes
	Contrarian	11.7	13.3	0.005	Yes
	Insight	22.4	20.0	0.008	Yes
	Value	13.3	13.3	0.006	Yes
	Opportunity	13.3	13.3	0.006	Yes
M03-21a-TC & M03-21b-TC	Curiosity	21.1	20.0	0.000	Yes
	Contrarian	17.4	13.3	0.000	Yes
	Insight	16.1	20.0	0.000	Yes
	Value	14.1	13.3	0.000	Yes
	Opportunity	14.1	13.3	0.000	Yes

4.1.2 Learning from Failure (LFF) Module

The results of the statistical analysis comparing the difference in the median Student EML Index for two pairs of course sections are shown in Table 4.3. These results are in agreement with those in Table 3.14 for the difference in the proportion of students at or above the threshold for all KSOs.

Table 4.3: Statistical Comparison Results of EML Index for LFF Module

Course Sections Compared	KSO	Difference in Course (Mean) EML Index	Difference in Median Student EML Index	*p*-Value	Is Difference Statistically Significant?
M03-11-LFF & M03-21a-LFF	Contrarian	–2.4	0.0	0.170	No
	Insight	–0.1	0.0	0.497	No
	Risk	–2.5	–5.0	0.315	No
	Failure	–2.5	–5.0	0.315	No
	Feasibility	–1.9	–3.3	0.308	No
	Validate	0.7	0.0	0.892	No
M03-21a-LFF & M03-21b-LFF	Contrarian	3.0	0.0	0.292	No
	Insight	3.6	6.6	0.087	No
	Risk	5.3	5.0	0.249	No
	Failure	5.3	5.0	0.249	No
	Feasibility	2.7	1.6	0.335	No
	Validate	1.3	0.0	0.527	No

4.1.3 Cost of Production (CoP) Module

Similar statistical analysis was carried out to determine if the difference in the median Student EML Index for two sections of the course in which the *Cost of Production* module was deployed was statistically significant. The results are shown in Table 4.4 and the statistical significance of the difference in the EML Index is in full agreement with the statistical significance of the difference in proportion for KSOs shown in Table 3.16.

Table 4.4: Statistical Comparison Results of EML Index for CoP Module

Course Sections Compared	KSO	Difference in Course (Mean) EML Index	Difference in Median Student EML Index	*p*-Value	Is Difference Statistically Significant?
M03-02-CoP & M03-29-CoP	Contrarian	0.0	0.0	0.349	No
	Insight	20.0	0.0	0.822	No
	Value	0.0	0.0	0.349	No
	Opportunity	0.0	0.0	0.349	No
	Market	0.0	0.0	0.195	No
	B_Model	0.0	0.0	0.349	No
	Feasibility	0.0	0.0	0.854	No
	Policy	0.0	0.0	0.349	No
	Economic	9.0	0.0	0.556	No

4.1.4 Effective Teams (ET) Module

Similar statistical analysis was carried out to determine if the difference in the EML Index for two sections of the course in which the *Effective Teams* module was deployed was statistically significant. The results are shown in Table 4.5. In comparing the statistical significance of the difference in the EML Index to the statistical significance of the difference in proportion for KSOs shown in Table 3.18, there is a discrepancy for sections M03-04-ET and M03-08-ET. The difference in the EML Index for these two course sections is statistically significant at the 95% confidence level for all three KSOs, but the difference in the proportion of students at or above the threshold for the three KSOs is not statistically different. However, in Table 3.18, the zero proportion is at the right margin of the confidence interval for each KSO, and therefore the null hypothesis just barely avoids being rejected. Hence, the difference between the two approaches is understandable.

Table 4.5: Statistical Comparison Results of EML Index for ET Module

Course Sections Compared	KSO	Difference in Course (Mean) EML Index	Difference in Median Student EML Index	*p*-Value	Is Difference Statistically Significant?
M03-03-ET & M03-04-ET	Insight	–3.1	–5.5	0.584	No
	Risk	3.8	2.2	0.155	No
	Team	1.0	–2.5	0.906	No
M03-04-ET & M03-08-ET	Insight	–9.6	–8.8	0.000	Yes
	Risk	–6.7	–6.6	0.000	Yes
	Team	–20.5	–20.0	0.000	Yes

CHAPTER 5. STUDENT ACHIEVEMENT OF KSO'S AFTER COMPLETING MULTIPLE INTEGRATED E-LEARNING MODULES

After completing multiple integrated e-learning modules, students will generally have deepened their EM. In order to assess the overall learning of KSO k by completing multiple modules Harichandran et al. (2019) proposed the Overall EML Index given by

$$I_k = \max(I_{k,1}, I_{k,2}, \dots, I_{k,T}) \tag{5-1}$$

The results for Overall EML Index values are displayed in Figure 5.1 for students who completed the TC, LFF, CoP and ET modules. The *Customer*, *Societal*, *Supply Chain* and *IP* KSOs were not addressed by any of these four modules and therefore students did not make progress toward these four KSOs by completing these modules. The maximum EML Index that students could achieve are shown as black bars in Figure 5.1. Clearly, there is room for student learning to improve through more effective integration of the e-learning modules in some of the courses.

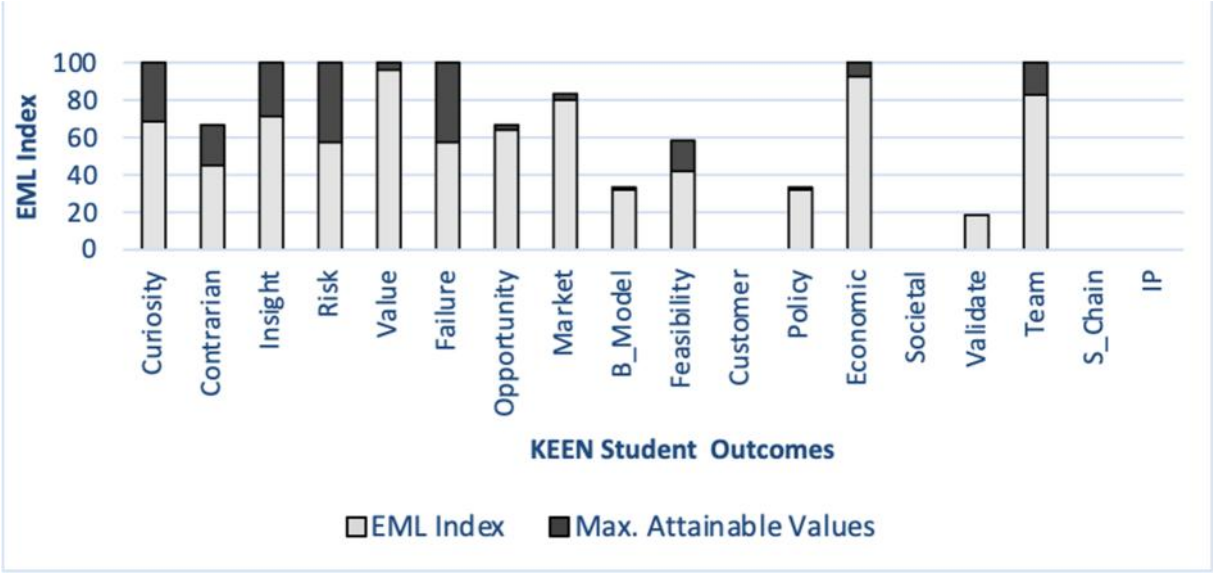

Figure 5.1: Overall EML Index for students completing the TC, LFF, CoP and ET modules

To extend the approach of using the proportion of students performing at or above a threshold to assess learning that occurs by completing multiple integrated e-learning modules, the proportions for KSOs were pooled across the different course sections for each module and then the proportion of students at or above the KSO threshold was computed. Then, consistent with the approach used with the EML Index, the maximum value of the proportion of students at or above the threshold for a given KSO was taken as the measure of student learning related to that KSO by completing multiple integrated e-learning modules. The maximum proportion of students at or above the KSO threshold after completing the TC, LFF, CoP and ET modules is shown in Table 5.1 and graphically displayed in Figure 5.2. The maximum proportion that could have been attained is always 100% and is shown as black bars.

Table 5.1: Proportion of Students at or Above KSO threshold After Completing Four Modules

KSO	Proportion at or Above Threshold	Max. Attainable Proportion
Curiosity	77%	100%
Contrarian	98%	100%
Risk	94%	100%
Value	98%	100%
Failure	56%	100%
Opportunity	98%	100%
Market	98%	100%
B-model	98%	100%
Feasibility	98%	100%
Customer	0%	100%
Policy	98%	100%
Economic	93%	100%
Societal	0%	100%
Validate	74%	100%
Team	92%	100%
S-chain	0%	100%
IP	0%	100%

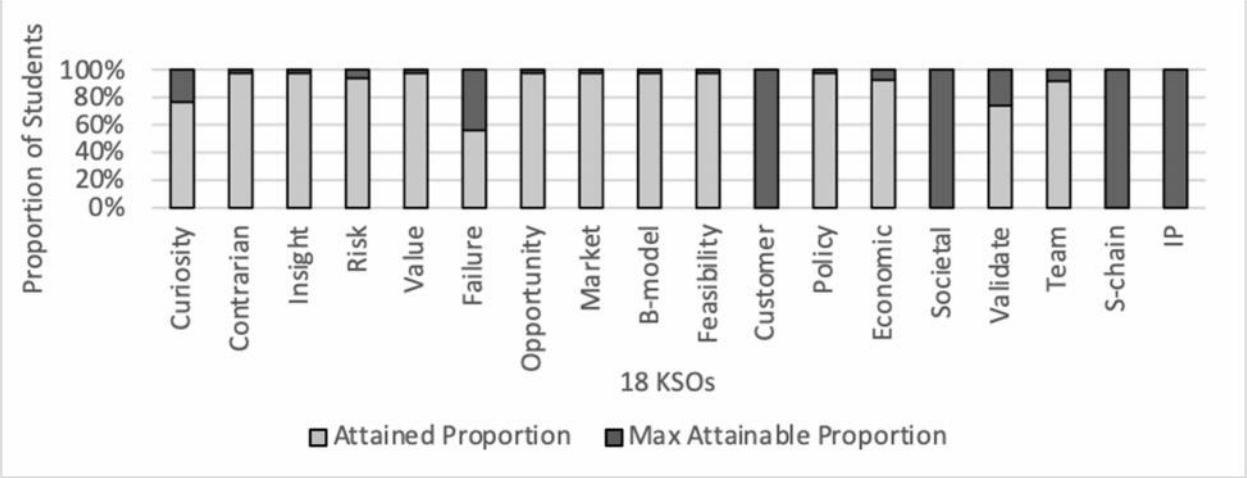

Figure 5.2: Proportion of students at or above KSO threshold
after completing TC, LFF, CoP and ET modules

The trend (i.e., skyline) of the bars in Figure 5.1 and Figure 5.2 are somewhat different and therefore the estimation of overall learning from the two approaches is different. In general, the proportion approach gives much higher estimates of student learning than the EML Index approach. The EML Index approach seems to give more reasonable estimates.

Insight into why the EML Index provides more reasonable results compared to the proportions approach can be obtained by examining the way in which the performance of each student is quantified. The Module Specific Student EML Index given by Eq. 4-3 considers both the depth to which a KSO is covered by the module as well as how well students performed in related activities. When determining the proportion of students who performed at or above a threshold, the depth to which a KSO is covered by the module is not considered. The maximum normalized achievement score that a student can obtain for any KSO in Table 3.10 is 1.67 (i.e., the maximum AO rating of 5 divided by the AO threshold level of 3). The percentage of the normalized achievement score, which is analogous to the Student EML Index, can be obtained by dividing the normalized achievement scores in Table 3.10 by 1.67 and multiplying by 100. Now the maximum score a

student can receive is 100 and the threshold for satisfactory performance becomes 60 (i.e., normalized achievement score of 1.0 divided by 1.67 and multiplied by 100).

The Student EML Index and the percentage normalized achievement score for each KSO for a student who received a rating of 4 for each of the four assessment outcomes in the TC module are shown in Table 5.2. For the *Curiosity* KSO, both the Student EML Index and the percentage normalized achievement score are the same (i.e., 80). This occurs because the two assessment outcomes that map to the *Curiosity* KSO have the highest depth of coverage of 3 (see Table 3.8). This also occurs for the *Insight* KSO for which the only assessment outcome that maps to it has a depth of coverage of 3. However, for the *Contrarian*, *Value* and *Opportunity* KSOs the Student EML Index is 53, while the percentage normalized achievement score remains at 80. This is because the depth of coverage of the assessment outcomes is only 2 for these KSOs (see Table 3.8) and the Student EML Index properly accounts for the fact that students cannot achieve full depth for these KSOs from the TC module. The percentage achievement score, however, does not consider the depth of coverage of the KSOs by the TC module and only quantifies student achievement relative to the material presented in the TC module and therefore yields a much higher percentage score compared to the Student EML Index. This is why for a given KSO the proportion of student who are at or above the threshold is generally much higher than the Course EML Index. This can be observed by comparing the heights of the bars in Figure 3.10 to those in Figure 4.1. Therefore, the approach using the proportion of students who meet or exceed a threshold level overestimates student learning because it does not consider the depth of coverage of KSOs by the e-learning modules, while the EML Index provides a much more reasonable estimate.

Table 5.2: Student EML Index and Percentage of the Normalized Achievement Scores for *TC* Module (M03-23-TC)

Approach	**AO1**	**AO2**	**AO3**	**AO4**	**Curiosity**	**Contrarian**	**Insight**	**Value**	**Opportunity**
EML Index	4	4	4	4	80	53	80	53	53
Proportion	4	4	4	4	80	80	80	80	80

The main weakness of both assessment methods discussed is that they are performed in the aggregate across all students in a course without tracking individual students. When learning that occurs by completing multiple integrated e-learning modules is assessed, the students in each course are not the same. This weakness is a result of the anonymous data collection that was done. If data was collected with student names or ID numbers, then the analysis could have been performed for each student completing a given number of e-learning modules and then averaged across students. Learning assessed at the student level rather than the class level would be more powerful.

CHAPTER 6. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

6.1 Summary and Conclusions

Two direct assessment techniques are proposed to assess entrepreneurial minded learning (EML) of students completing integrated e-learning modules. The first approach uses the proportion of students in a course who perform at or above an acceptable threshold level on specified assessment outcomes. By mapping the assessment outcomes to 18 KEEN Student Outcomes (KSOs) with appropriate weights, this approach is extended to assess student achievement of the KSOs. The second approach uses the EML Index proposed by Harichandran et al. (2019) to assess student achievement of KSOs. The EML Index provides better estimates of student learning because it considers the depth of coverage of each KSO by the e-learning modules, while the approach using proportions does not.

A bootstrap method applicable to small datasets to determine if the difference in the proportion of students who perform at or above the threshold in two course sections that deploy the same e-learning module are statistically significant is described. This method is used to compare student performance in several pairs of course sections that deployed the same e-learning module.

The EML Index for individual students were discrete and not normally distributed. Therefore, the difference in the median Student EML Index for two course sections that deployed the same e-learning module were compared using the Mann-Whitney test. In most cases, the median Student EML Index was very similar to the Course EML Index (mean), and therefore the comparisons also apply to the Course EML Index.

In general, comparison tests of student performance in two sections of a course based on the proportion of students who perform at or above the threshold and the EML Index were in agreement.

Student achievement of KSOs by completing multiple e-learning modules was assessed using the Overall EML Index proposed by Harichandran et al. (2019). The approach using the proportion of students who perform at or above an acceptable threshold was also extended to assess student achievement of KSOs by completing multiple e-learning modules. The two approaches gave rather different assessments of student achievement of KSOs through multiple integrated e-learning modules with the EML Index approach giving more reasonable estimates. The proportions approach yielded very high estimates of student learning.

The findings related to the research questions are listed in Table 6.1.

Table 6.1: Research Findings addressing the Research Questions

Research Questions	**Research Findings**
1. Are the proportion of students who receive acceptable grades in EML assessment outcomes an effective measure of student learning of entrepreneurial concepts?	Yes, the proportion of students in a course who score at or above the threshold of 3 is a reasonable measure of student learning of the AOs.
2. Can differences between classes of the proportion of students who receive acceptable grades in EML assignments be used to identify instructors' pedagogical strengths and weaknesses?	Maybe. Statistically significant differences could indicate differences in instructor effectiveness, but they could also indicate different grading standards or differences in student's abilities.
3. Can student performance in generic EML assessment outcomes be used to assess achievement of KEEN Student Outcomes (KSOs)?	Yes, but they overestimate student learning. The assessment outcomes can be mapped to KSOs, acceptable thresholds can be established for the KSOs, and the proportion of students at or above these thresholds can be computed. However, these proportions overestimate student achievement of KSOs because they do not account for the depth of coverage of the KSOs by the e-learning modules.

4. Is the EML Index an effective measure of student achievement of KSOs?	Yes, the EML Index provides a reasonable estimate of student learning of KSOs because it accounts for the depth of coverage of the KSOs by the e-learning modules.
5. Can differences in the EML Index between different classes be used to identify instructors' pedagogical strengths and weaknesses?	Maybe. Comparisons between classes gives similar results as with proportions. Statistically significant differences could indicate differences in instructor effectiveness, but they could also indicate different grading standards or differences in student's abilities.
6. Can student achievement of KSOs in multiple courses with integrated e-learning modules be assessed?	Both the EML Index and the proportion of students who meet or exceed KSO thresholds can be adapted to assess student achievement of KSOs by completing multiple e-learning modules. However, the proportions approach gives very high estimates, while the EML Index approach gives reasonable estimates.

6.2 Recommendations for Future Work

The main shortcoming of the study described in this thesis is that all assessments were done in the aggregate at the course level without tracking individual students. This limitation was a result of the anonymous data collection where student names and IDs were not tracked.

Future work should extend the analysis described in this thesis to data collected with student names or IDs. This would enable student achievement of KSOs by completing multiple integrated e-learning modules to be determined for each individual student. Averaging performance across students could then be done to effectively assess the success of the integrated e-learning modules at the program level.

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