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EML Indices to Assess Student Learning through Integrated e-Learning Modules

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EML Indices to Assess Student Learning through Integrated e-Learning Modules

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Ron Harichandran is Dean of the Tagliatela College of Engineering and is the PI of four grants related to the development of an entrepreneurial mindset in students by utilizing integrated e-learning modules and experiential learning opportunities. Through these grant entrepreneurial thinking is being integrated into courses spanning all four years in seven ABET accredited engineering and computer science BS programs, and 75 engineering and computer science faculty at 53 other universities were trained and deployed modules in their courses.

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

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

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Jean Nocito-Gobel, Professor of Civil & Environmental Engineering at the University of New Haven, received her Ph.D. from the University of Massachusetts, Amherst. She has been actively involved in a number of educational initiatives in the Tagliatela College of Engineering including KEEN and PITCH,

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EML Indices to Assess Student Learning through Integrated e-Learning Modules

Introduction

The University of New Haven has facilitated the development and integration of 18 e-learning modules on entrepreneurial topics into regular engineering and computer science courses. In addition to faculty at the University of New Haven, over three years 77 faculty at 53 other universities in the US have also integrated these modules into their courses. These modules are designed so that students learn entrepreneurial content outside of class and then apply them to a class project or assignment (i.e., contextual activities). Instructors are also strongly encouraged to engage students through online or in-class discussions related to the module content. Finally, instructors are expected to assess student learning through their performance in the contextual activities and through exam questions related to the module content.

Indirect assessment using content-specific surveys administered before and after students complete modules showed that students learn entrepreneurial concepts effectively through the integrated e-learning modules [1-2]. Feedback collected from faculty deploying the modules and students completing them also confirmed the value that these modules deliver [1].

Direct assessment of learning is much stronger than indirect assessment [3]. Direct assessment is usually achieved by grading student work to determine how well they achieve defined learning outcomes. This is easily accomplished if the student work is directly related to the learning outcomes. When the student work is more broadly related to the learning outcomes, the grades for different components will usually need to be distributed to related learning outcomes with appropriate weights. Learning can be assessed by the proportion of students who score above a set threshold (for example 75%) for each of the learning outcomes.

With the aim of obtaining direct assessment of student learning, we developed assessment rubrics for each module based on 3-5 learning outcomes that instructors could use to evaluate student performance on contextual activities and exam questions. The rubrics quantify qualitative assessments of student work. The direct assessment provided even stronger evidence of the effectiveness of the e-learning modules [4].

The e-learning modules, instructor guides that provide instructions on integration strategies and examples of contextual activities, the assessment rubrics, and other resources are freely available to the public [5].

Our goal in creating the e-learning modules was to use them collectively to develop an entrepreneurial mindset (EM) in engineering and computer science students. We defined EM through the student outcomes and skills in the KEEN framework [6]. To assess whether we were accomplishing our goal, we related the content of the e-learning modules to the student outcomes and skills in the KEEN framework. It would be useful to develop a learning index that could measure how well students achieve an EM. The use of learning indices is rare in the literature. In order to measure lifelong learning in communities, the Canadian Council on Learning proposed a Composite Learning Index that assembled 26 measures of 17 indicators into a single learning index [7, 8]. In this paper, we propose indices to measure how well students develop an EM by completing one or more integrated e-learning module(s) in their courses.

The seven modules assessed in this paper and the abbreviations used to refer to them are listed in Table 1. The KEEN student outcomes (KSOs) and the abbreviations used to refer to them are listed in Table 2.

Table 1. E-Learning Modules Assessed

Module Name	Short Name (Abbreviation)
Thinking creatively to drive innovation	Thinking creatively (TC)
The elevator pitch: advocating for your good ideas	Elevator pitch (EP)
Learning from failure	Learning from failure (LFF)
Adapting a business to a changing climate	Adapting a business (AB)
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)
Applying systems thinking to complex problems	Systems thinking (ST)

Table 2. 18 KEEN Student Outcomes (KSOs) and Abbreviations

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

Relating Module Content to the KEEN Framework

Each e-learning module has a set of learning outcomes [4]. For the purpose of assessing student work related to each module, we proposed 3-5 assessment outcomes (AO) that were typically a subset or a combination of the learning outcomes. The assessment outcomes for the seven modules considered in this paper are listed in Table 3. We mapped how well the content of each module addressed the KEEN student outcomes (KSOs) by assigning a depth of coverage to each KSO addressed by each assessment outcome in a module, with 3=High, 2=Medium, 1=Low and 0=No coverage. These are essentially weights assigned to the assessment outcomes for each KSO. These mappings for the seven modules are shown in Table 4; the weight of 0 is omitted to improve readability. Each module covers only a few of the KSOs and in order for students to learn most of the KSOs they will need to complete multiple modules in several courses.

Table 3. Assessment Outcomes for the Seven Modules

Module	AO1	AO2	AO3	AO4	AO5
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)	
Elevator pitch (EP)	Made an argument for exigency	Provided a non-technical explanation of the solution	Clearly stated a value proposition	Provided a clear path to move forward	Implemented strategies for recovering from an unsuccessful pitch experience
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	
Adapting a business (AB)	Explained the ways in which a company was impacted by changing business conditions	Described the various factors that made up the market and business conditions	Performed environmental scanning of the business environment	Described ways in which a firm dealt with changes in its business environment	
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	
Systems thinking (ST)	Identified system or systems architecture of the project or process	Decomposed the system hierarchy to at least four levels	Defined a system from various perspectives, including technical feasibility, value, risk, and societal impact	Applied the heuristic architecting method to develop a system architecture	

Table 4. Depth of Coverage of KSOs by Modules (i.e., Weights Assigned to Assessment Outcomes)

Module →	TC				EP					LFF				AB				CoP			ET				ST			
	AO1	AO2	AO3	AO4	AO1	AO2	AO3	AO4	A05	AO1	AO2	AO3	AO4	AO1	AO2	AO3	AO4	AO1	AO2	AO3	AO1	AO2	AO3	AO4	AO1	AO2	AO3	AO4
KSO ↓																												
Curiosity			3	3										2														
Contrarian			2				1				1							1										
Insight				3	3	3	3	2	1			2	2	3	3	3	3	2	2	2	2	1	1	0	2	2	2	2
Risk										3	3	3	3	2	2	2	2					1	1	1		1	2	
Value			2	2	3		3											3									1	
Failure									2	3	3	3	3	2			2											
Opportunity			2	2	3	3	3	3										2										
Market					3	2	3							3	3	3	3	3		2								
B-model																		1										
Feasibility					3	2	3	2		3	2	1	1	3	3	2	3	1	2	1							3	
Customer																												
Policy																				1								
Economic							3	3						2	3	2	3		3								2	
Societal					3	3	3							1	3												2	
Validate					1		1	1				1		1	1	2	1											
Team																					3	3	3	3				
S-chain																												
IP																												

Quantifying Student Achievement of KSOs through an Integrated E-Learning Module

Instructors deploying an e-learning module used the rubric provided to them containing the corresponding assessment outcomes listed in Table 3 to rate each student's performance on a scale from 1 to 5, with 1=Poor, 2=Below Average, 3=Average, 4=Above Average, and 5=Outstanding. These ratings were based on the course contextual activities and exam questions related the module. While the ratings across all students are indicative of how well students in the course achieved the assessment outcomes related to the module, they do not reflect how well students in the course achieved the KSOs. A Module Specific Entrepreneurial Minded Learning (EML) Index is proposed to quantify how well students attain each KSO through completion of a given e-learning module and the related contextual activities used by the instructor for the course into which the module was integrated. The Module Specific EML Index, $I_{k,\mathrm{m}}$, for KSO k achieved through module m is defined as

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

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 $k = 1,\ldots,18$ (there are 18 KSOs) and $m = 1,\ldots,18$ (there are 18 e-learning modules). If all the weights are zero for all assessment outcomes and a given k, then $I_{k,m} = 0$. The number 15 in the denominator of Eq. 1 is the maximum weight of 3 multiplied by the maximum student rating of 5. It is important to only use the number of assessment outcomes for KSO k that have non-zero weights in the denominator of Eq. (i.e., $t_{w\neq 0}$), because otherwise assessment outcomes for modules m that are not related to KSO k will diminish the Module Specific EML Index, which is unreasonable. Since the index $I_{k,m}$ is averaged across all students, it reflects the average achievement of KSO k by all students in the class and not the achievement of a specific student.

The maximum value of the Module Specific EML Index for KSO k attainable through module m occurs when all students receive the maximum assessment rating of 5 for all of the module's assessment outcomes. This maximum value is given by

$$I_{k,m,max} = 100 \sum_{q=1}^{t} \frac{w_{k,q,m}}{3 t_{w \neq 0}} \tag{2}$$

If all the weights are zero for all assessment outcomes and a given k, then $I_{k,m,max} = 0$.

How well students achieve KSO k through the e-learning module m and the contextual activities deployed by the instructor in the course can be quantified through the normalized Module Specific EML Effectiveness Index

$$E_{k,m} = \frac{I_{k,m}}{I_{k,m,max}} \quad (3)$$

When students complete multiple courses with integrated e-learning modules they have the opportunity to broaden and deepen their knowledge, and if they demonstrate stronger achievement of KSO k, then their EML Index for that KSO should increase. The logical definition of the overall EML Index attained through completion of r integrated e-learning modules is

$$I_k = \max(I_{k,1}, I_{k,2}, \dots, I_{k,r}) \quad (4)$$

The indices proposed above improve on preliminary versions suggested previously [4].

A Simplified Illustration of the Learning Index

We provide an illustration of the learning index through a simple fictitious example involving arithmetic. Assume that two e-learning modules are used to help students learn arithmetic; Module A/S that covers addition and subtraction, and Module A/S/M/D that covers addition, subtraction, multiplication and division. The assessment outcomes for these two modules are shown in **Error! Not a valid bookmark self-reference.**. The four learning outcomes related to arithmetic (akin to the KSOs) are: (1) the ability to do *addition*; (2) the ability to do *subtraction*; (3) the ability to do *multiplication*; and (4) the ability to do *division*. The depth of coverage (weights) of each learning outcome related to the assessment outcomes are shown in Table 6. Let's assume that Module A/S/M/D does not cover division completely (e.g., omits long division) and therefore the depth of coverage is 2 for division.

Table 5. Assessment Outcomes for Arithmetic Modules

Module	AO1	AO2	A03	A04
A/S	Demonstrated the ability to add	Demonstrated the ability to subtract		
A/S/M/D	Demonstrated the ability to add	Demonstrated the ability to subtract	Demonstrated the ability to multiply	Demonstrated the ability to complete the type of division problems covered in the module

Table 6. Depth of Coverage of Learning Outcomes

Module →	A/S		A/S/M/D			
Assessment Outcomes →	AO1	AO2	AO1	AO2	AO3	AO4
Learning Outcome ↓						
Addition	3		3			
Subtraction		3		3		
Multiplication					3	
Division						2

Let's assume that the two e-learning modules on arithmetic were integrated into two sections of two courses. Course 1 integrated Module A/S and all students in Section 1 received a

rating of 4 out of 5 for both assessment outcomes, while students in Section 2 received a rating of 3 for both assessment outcomes (either because the students were weaker or because the instructor/integration was not as effective). Course 2 integrated Module A/S/M/D and all students in Section 1 received a rating of 5 for all four assessment outcomes, while students in Section 2 received a rating of 4 for the four assessment outcomes. Students' skills in addition and subtraction improved from the first to the second course. The learning indices computed by Eqs. 1-3 for the two courses are shown in Table 7.

Table 7. Learning Indices for Deployment of Arithmetic Modules in Two Courses

LO (*k*)	**Course 1 (Module A/S)**						**Course 2 (Module A/S/M/D)**					
	Section 1			**Section 2**			**Section 1**			**Section 2**		
	$I_{k,1}$	$I_{k,1,max}$	$E_{k,1}$	$I_{k,1}$	$I_{k,1,max}$	$E_{k,1}$	$I_{k,2}$	$I_{k,2,max}$	$E_{k,2}$	$I_{k,2}$	$I_{k,2,max}$	$E_{k,2}$
Addition	80	100	80	60	100	60	100	100	100	80	100	80
Subtraction	80	100	80	60	100	60	100	100	100	80	100	80
Multiplication	0	0	0	0	0	0	100	100	100	80	100	80
Division	0	0	0	0	0	0	67	67	100	54	67	80

The data shown in Table 7 may be interpreted as follows:

1. Module A/S, which fully covers addition and subtraction, can have a maximum learning index of 100 for these two learning outcomes if the students receive the maximum rating of 5 for the two assessment outcomes. However, since students in Section 1 received a rating of 4 and students in Section 2 received a rating of 3, both the learning index and the learning effectiveness index are 80 and 60 for Sections 1 and 2, respectively. The learning effectiveness index measures how well students did relative to the maximum they could have achieved. Since this module does not cover multiplication or division, all indices related to these learning outcomes are zero.
2. Module A/S/M/D, which fully covers addition, subtraction and multiplication, but only partially covers division, can only achieve a maximum learning index of 67 for division if all students receive the maximum rating of 5 for assessment outcome 4 as in Section 2. This is appropriate, since students cannot learn the elements of division that are not covered in the module (e.g., long division). However, if students learn all the division techniques covered in the module, then the learning effectiveness index is 100 as in Section 1; i.e., the module and contextual activities were fully effective in enabling students to learn what was covered in the module. When the student ratings are lower, then the learning index will be less than 67, as in Section 2, but the maximum achievable value of the learning index is still 67, and the learning effectiveness index drops below 100 because students did not demonstrate that they learned all the division techniques covered in the module.

Now if students in Sections 1 and 2 of Course 1 also completed Sections 1 and 2 of Course 2, respectively, then based on the data shown in Table 7, they not only improved their learning of addition and subtraction, but also learned multiplication and division. The overall learning index I_k for these students would then be given by the values shown in Table 8.

Table 8. Overall Learning Index when Students Completed Both Integrated Modules

LO (*k*)	**Section 1 (Both Courses)** I_k	**Section 2 (Both Courses)** I_k
Addition	100	80
Subtraction	100	80
Multiplication	100	80
Division	67	54

Module Specific EML Indices for Seven Modules Deployed at Multiple Institutions

The seven e-learning modules listed in Table 1 were integrated into engineering and computer science courses at multiple universities and colleges in 2017-18. All faculty deploying the modules were trained during a half-day workshop to develop appropriate contextual activities and perform assessments using the rubrics supplied to them. However, no attempt was made to assess or improve inter-rater reliability (i.e., unify the grading styles of instructors). The EML indices defined in Eqs. 1-3 were computed for each KSO for seven e-learning modules deployed at various institutions and the results are discussed below.

Examples of contextual activities that were used for select modules are given in the Appendix.

Thinking Creatively to Drive Innovation

The *Thinking Creatively* module was deployed at the University of New Haven and four other institutions. At the University of New Haven it was deployed in five different sections by four instructors (one instructor deployed it in two sections). The EML Index for the five KSOs covered in this module are shown in Figure 1. The labeling on the *x*-axis is an identifier with the following structure:

- A B, M or D is used as the first letter to denote programs that offer baccalaureates, master's or doctorates as the highest degree.
- The two digits following the first letter is a numeric code assigned to each institution.
- The two digits and optional letter between the two dashes is a code assigned to the instructor. If the same instructor deployed a module in multiple sections or courses, then the letter code "a", "b", … is used to denote the different sections/courses".
- The letters at the end denotes the e-learning module (e.g., TC = *Thinking Creatively*).

In addition to the ratings assigned to student performance, the magnitude of the EML Index depends on the weights shown in Table 4.

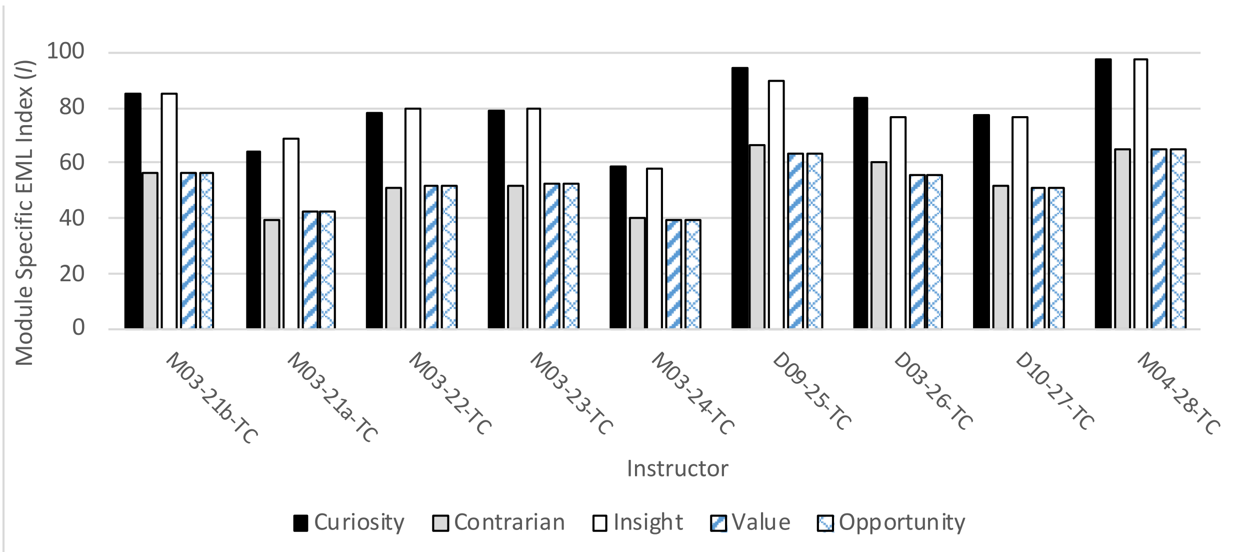

Figure 1. Module Specific EML Index for deployments of *Thinking Creatively*

The following observations are made from Figure 1:

- The EML Index for KSOs *Curiosity* and *Insight* are higher than for the other three KSOs for all deployments because the weights (i.e., depth of coverage) for these are 3, while those for the others are 2 (see Table 4).
- The highest EML Indices were for students at institutions M04 and D09. This could be because the instructors did an exemplary job with the deployments, the students learned the most in these courses, and/or the instructor ratings related to the assessment outcomes were generous.
- The five deployments at the University of New Haven (M03) indicate that students in instructor 24's class have the lowest EML Index. The reason for this could be that the students in that section were the weakest, the instructor was not particularly effective in the deployment, or the instructor provided lower ratings to students for the assessment outcomes.

  Further, students in section *a* of instructor 21's course had significantly lower EML Indices than students in section *b* of the same instructor's course. This is probably due to the students in section *a* being weaker than students in section *b*.

The Module Specific EML Effectiveness Index for the seven deployments is shown in Figure 2. This figure clarifies some of the observation made earlier:

- Based on the instructors' assessments, the students at institutions D09 and M04 learned 90% or more of what could be learned from the integrated e-learning module.
- Students in instructor 24's class at M03 only learned about 60% of what they could have. Either these students were particularly weak, the instructor did not integrate the module well into the class, or the instructor's assessment was harsh.

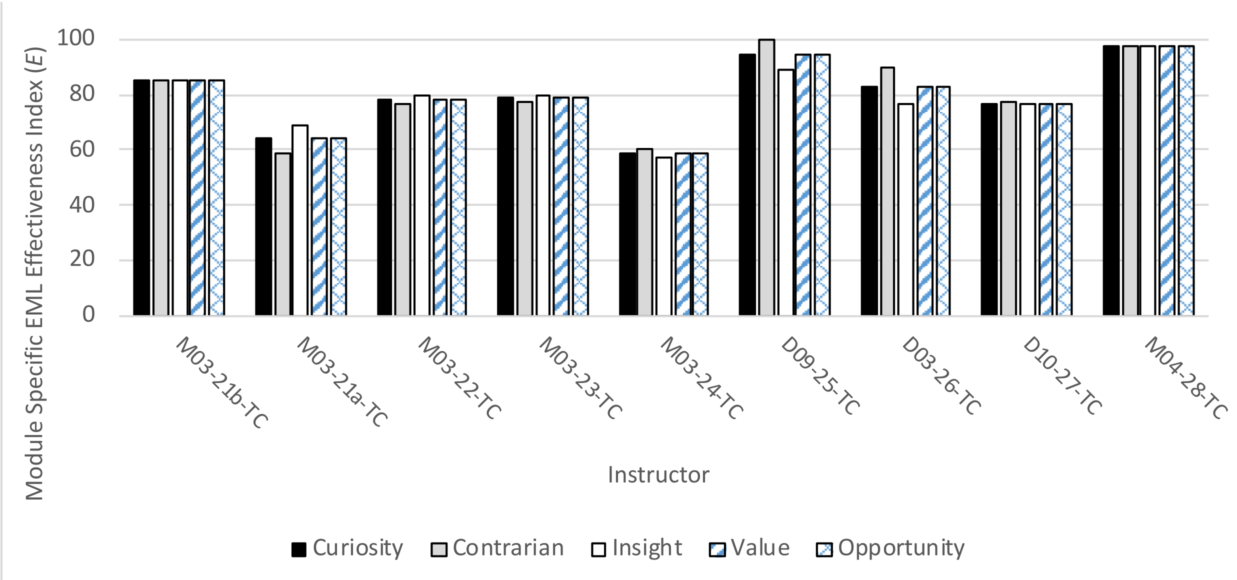

Figure 2. Module Specific EML Effectiveness Index for deployments of *Thinking Creatively*

The Elevator Pitch: Advocating for Your Good Ideas

The *Elevator Pitch* module was deployed at three different institutions, with one instructor deploying it in two different sections. The Module Specific EML Index and the Module Specific EML Effectiveness Index for the ten KSOs covered by the module are shown in Figure 3 and 4 for the four deployments. In addition to the ratings assigned to student performance, the magnitude of the EML Index depends on the weights shown in Table 4. This module only weakly covers the *Contrarian* and *Validate* KSOs (weight 1) and that is why the EML Index is low for these two KSOs.

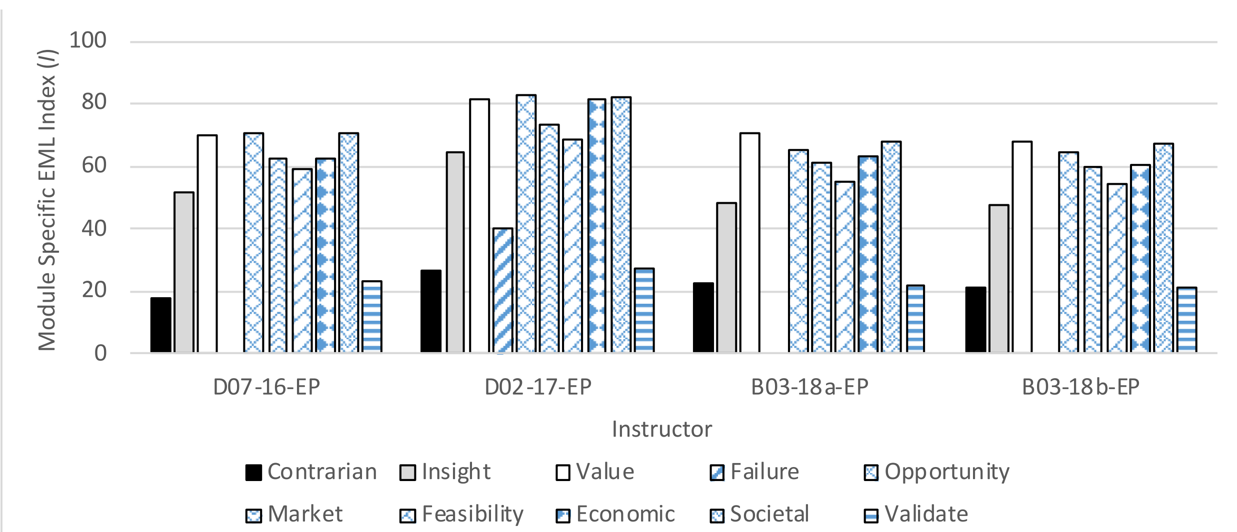

Figure 3. Module Specific EML Index for deployments of *Elevator Pitch*

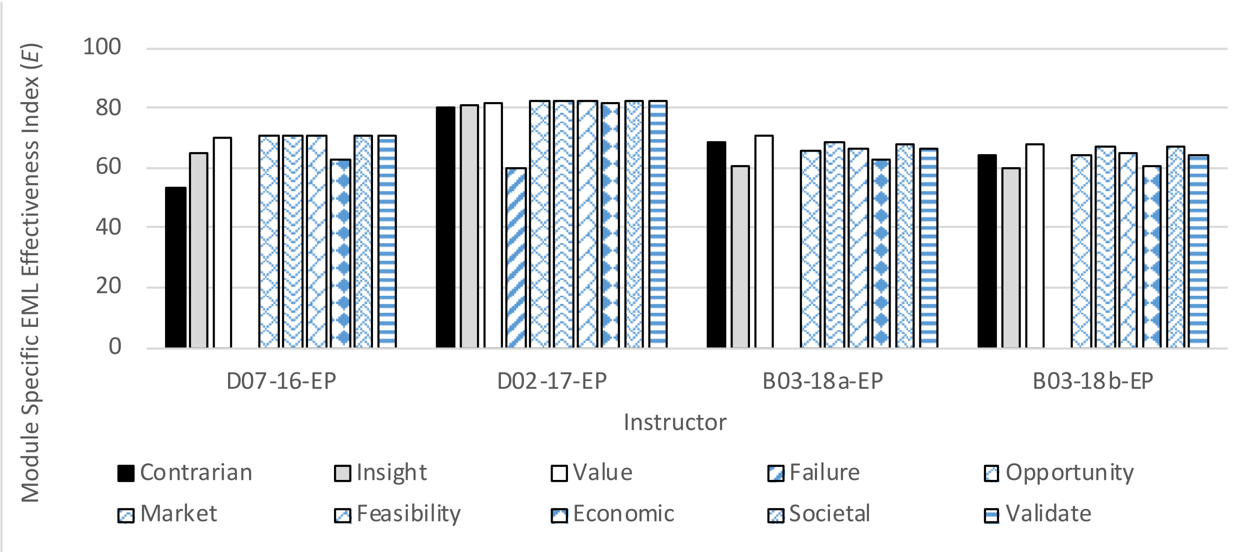

Figure 4. Module Specific EML Effectiveness Index for deployments of *Elevator Pitch*

The fifth assessment outcome for the *Elevator Pitch* module is "Implemented strategies for recovering from an unsuccessful pitch experience" (see Table 3). This assessment outcome requires that students are provided feedback on an initial pitch so that they can improve it in a subsequent pitch. Only institution D02 assessed the fifth outcome and as a result has a non-zero EML Index for the *Failure* KSO. Overall, the instructor at institution D02 appears to have been most effective and the students learned about 80% of what they could have through the integrated module.

While a high Module Specific EML Effectiveness Index most likely indicates that the instructor effectively integrated the e-learning module into the course, we cannot rule out the possibilities that the instructor was an "easy grader" or had bright students. This caveat applies to the discussions for all the modules.

Learning from Failure

The *Learning from Failure* module was deployed at two institutions. The Module Specific EML Index and the Module Specific EML Effectiveness Index for the six KSOs covered by the module are shown in Figure 5 and 6 for the two deployments. In addition to the ratings assigned to student performance, the magnitude of the EML Index depends on the weights shown in Table 4. The instructor at institution B02 appears to have been somewhat more effective than the one at institution M03 and the students in the former institution learned about 80% of what they could have learned through the integrated module for five of the KSOs.

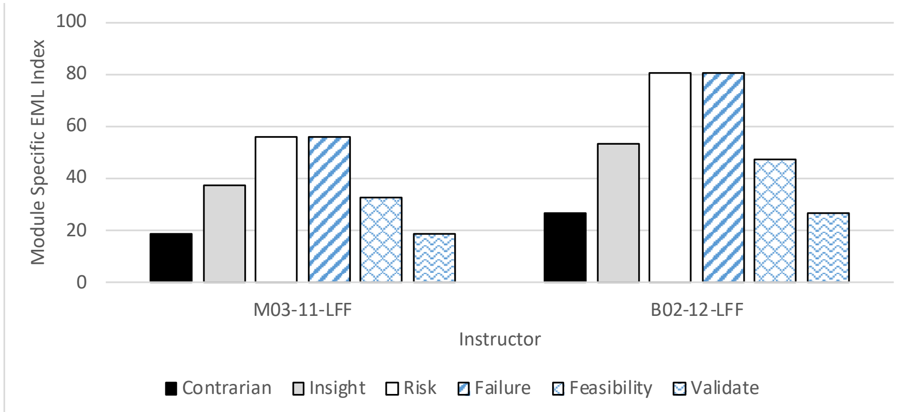

Figure 5. Module Specific EML Index for deployments of *Learning from Failure*

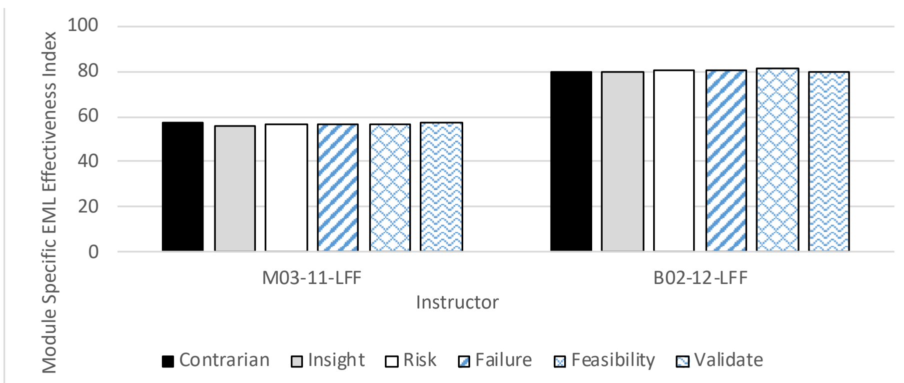

Figure 6. Module Specific EML Effectiveness Index for deployments of *Learning from Failure*

Adapting a Business to a Changing Climate

The *Adapting a Business* module was deployed at two institutions. The Module Specific EML Index and the Module Specific EML Effectiveness Index for the nine KSOs covered by the module are shown in Figure 7 and 8 for the two deployments. In addition to the ratings assigned to student performance, the magnitude of the EML Index depends on the weights shown in Table 4. The instructor at institution D08 appears to have been slightly more effective than the one at institution B04 and the students in the former institution learned about 90-95% of what they could have learned through the integrated module for the nine KSOs.

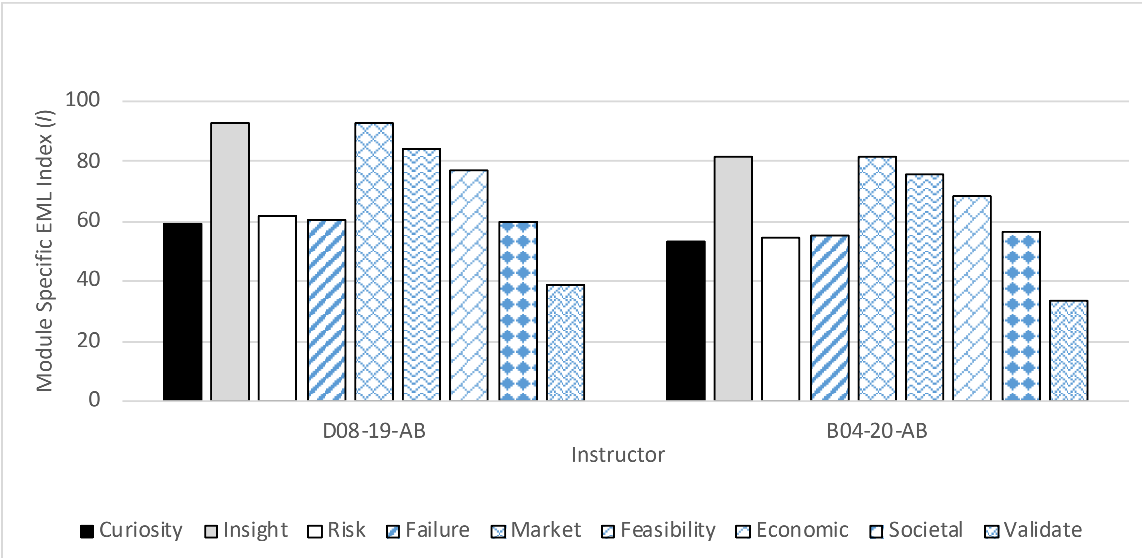

Figure 7. Module Specific EML Index for deployments of *Adapting a Business*

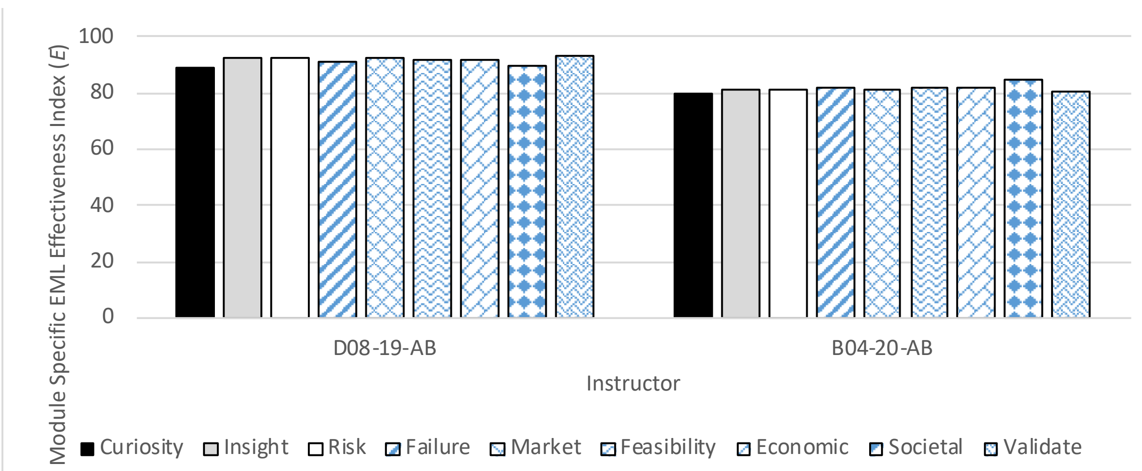

Figure 8. Module Specific EML Effectiveness Index for deployments of *Adapting a Business*

Establishing the Cost of Production or Delivery of a Service, including Scaling Strategies

The *Cost of Production* module was deployed at two institutions. The Module Specific EML Index and the Module Specific EML Effectiveness Index for the nine KSOs covered by the module are shown in Figure 9 and 10 for the two deployments. In addition to the ratings assigned to student performance, the magnitude of the EML Index depends on the weights shown in Table 4. The instructor at institution M03 appears to have been considerably more effective than the one at institution M01 and the students in the former institution learned about 96-97% of what they could have learned through the integrated module for the nine KSOs. There were only four

students in the course at institution M01, therefore the sample size was also small for this institution.

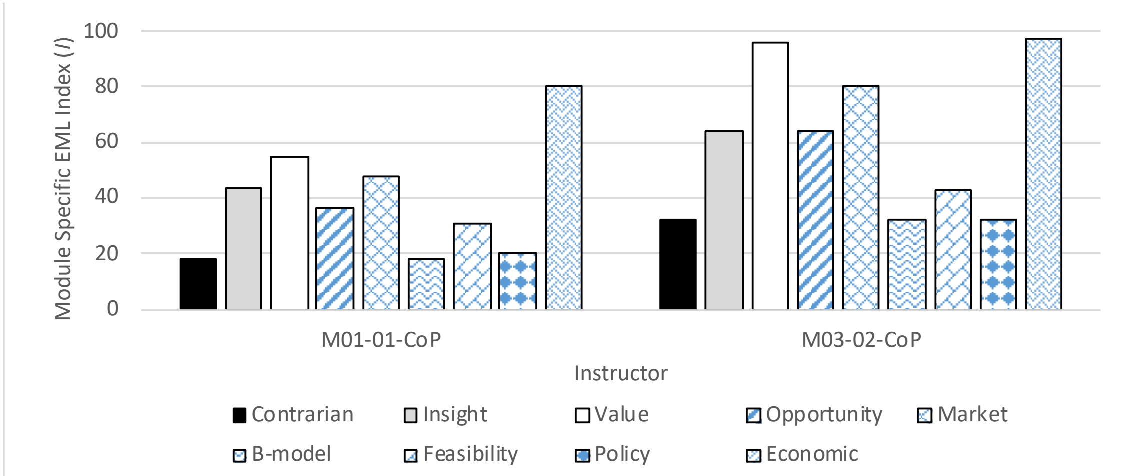

Figure 9. Module Specific EML Index for deployments of *Cost of Production*

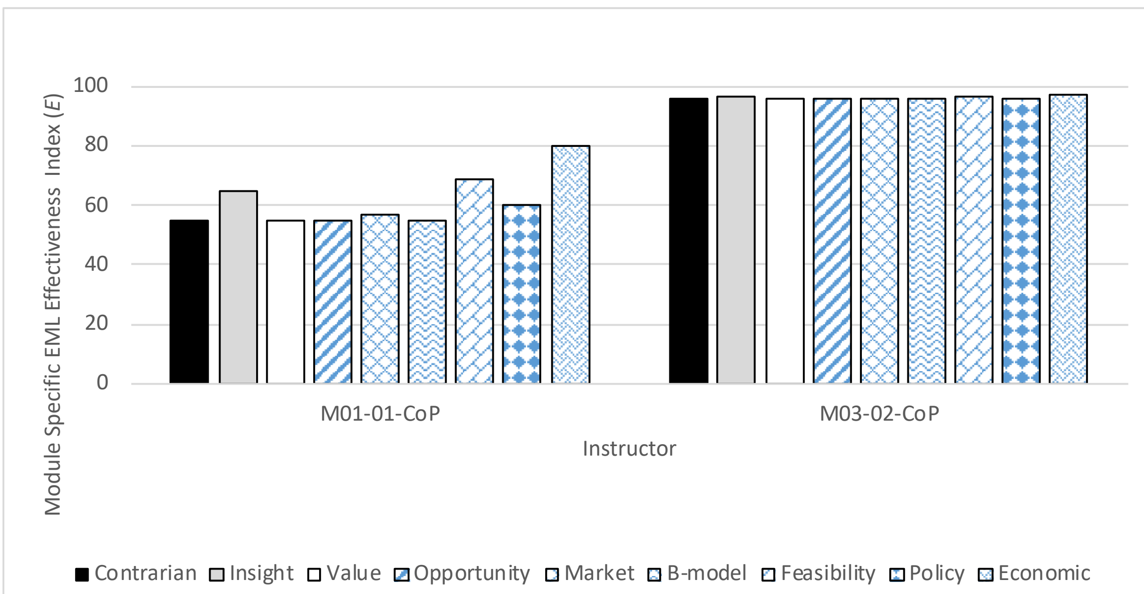

Figure 10. Module Specific EML Effectiveness Index for deployments of *Cost of Production*

Building, Sustaining and Leading Effective Teams and Establishing Performance Goals

The *Effective Teams* module was deployed at five institutions, with institution M03 deploying them in four different courses. The Module Specific EML Index and the Module Specific EML Effectiveness Index for the three KSOs covered by the module are shown in Figure 11 and 12 for the eight deployments. In addition to the ratings assigned to student

performance, the magnitude of the EML Index depends on the weights shown in Table 4. Instructor 08 at institution M03 appears to have been the most effective at deploying the module. The instructor at institution D05 only assessed one of the four assessment outcomes (AO3 based on a team charter) and therefore we can confirm that students in the class learned only 20-30% of what they could have from the integrated module. The deployment by the instructor at institution D05 was therefore weak.

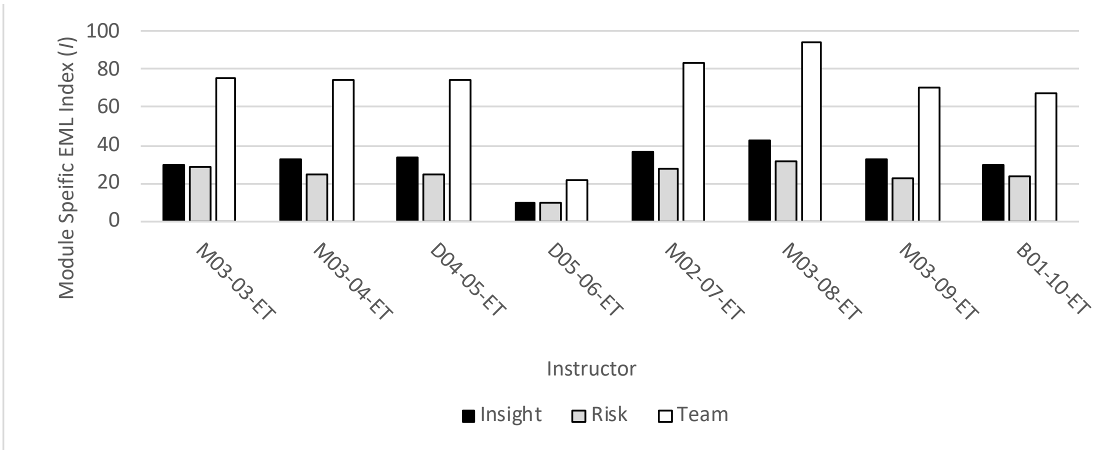

Figure 11. Module Specific EML Index for deployments of *Effective Teams*

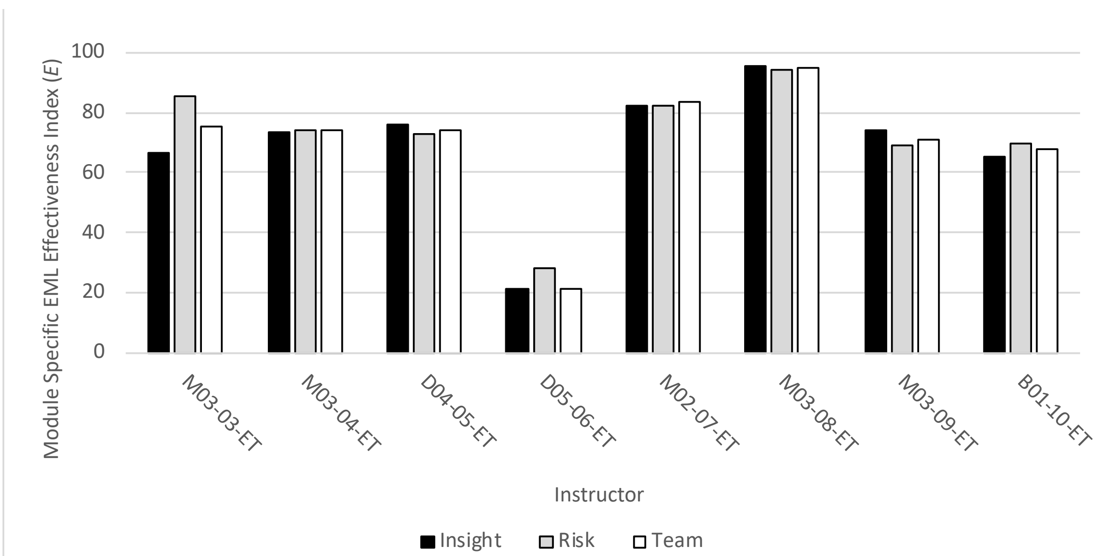

Figure 12. Module Specific EML Effectiveness Index for deployments of *Effective Teams*

Applying Systems Thinking to Complex Problems

The *Systems Thinking* module was deployed at three institutions. The Module Specific EML Index and the Module Specific EML Effectiveness Index for the six KSOs covered by the

module are shown in Figure 13 and 14 for the three deployments. In addition to the ratings assigned to student performance, the magnitude of the EML Index depends on the weights shown in Table 4. The instructor at institution D06 appears to have been most effective with students in the class learning about 78-85% of what they could learn from the integrated module. The students at institution D01 appear to have had considerable difficulty in achieving the KSOs "Value," "Feasibility," "Economic" and "Societal." Table 4 indicates that only assessment outcome 3—"Defined a system from various perspectives, including technical feasibility, value, risk, and societal impact"—is connected to these four KSOs. There were only 6 students at institution D01 and they did not perform well on this assessment outcome; the instructor should make changes to ensure that students learn more of these concepts.

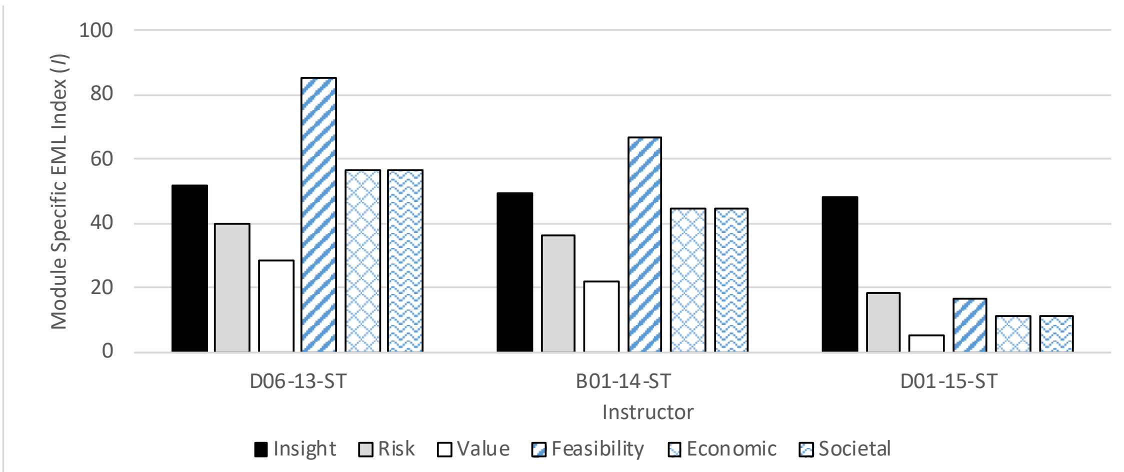

Figure 13. Module Specific EML Index for deployments of *Systems Thinking*

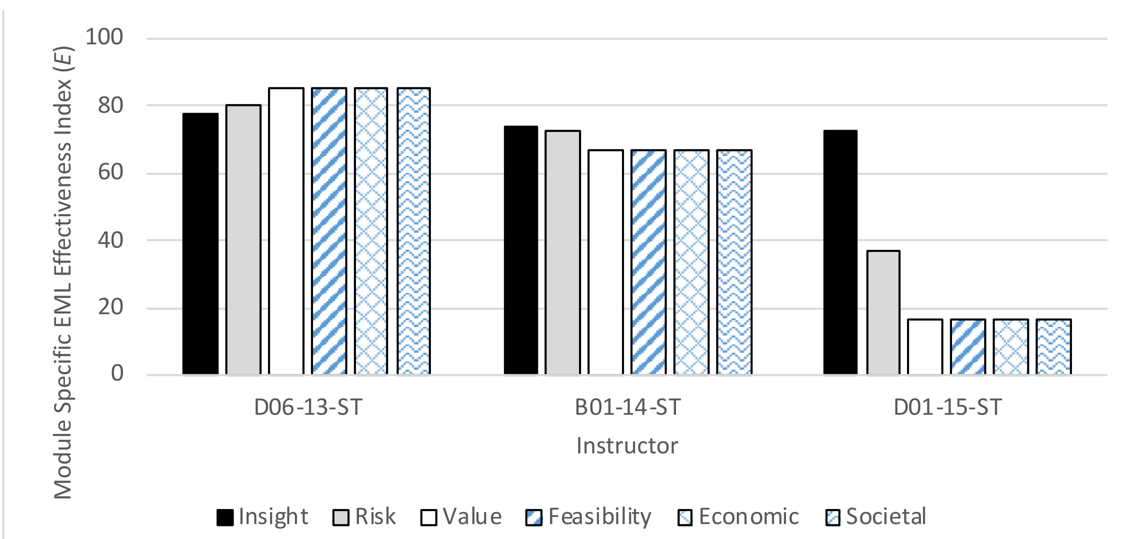

Figure 14. Module Specific EML Effectiveness Index for deployments of *Systems Thinking*

EML Index Reflecting KSO Achievement by Completing Several Integrated Modules

When students complete multiple integrated e-learning modules, either in one course or through multiple courses, they will both broaden and deepen their EM. The overall EML Index that is a measure of their achievement of the KSOs after completing multiple integrated modules is given by Eq. 4. At the present time, assessment results are available for four courses with integrated e-learning modules at the University of New Haven. The courses and the e-learning modules integrated into them are shown in Table 9. The first three modules listed in Table 9 are common courses taken by students from many disciplines. In their junior and senior years students completed courses specific to their disciplines.

Table 9. Courses and Modules Completed by Students at the University of New Haven

E-Learning Module	Course(s)
Thinking creatively to drive innovation (TC)	Introduction to Engineering (First-year)
Learning from failure (LFF)	Project Planning and Development (First-year)
Establishing the cost of production or delivery of a service, including scaling strategies (CoP)	Project Management and Engineering Economics (Sophomore)
Building, sustaining and leading effective teams and establishing performance goals (ET)	(Junior/Senior Courses) Chemical Engineering Laboratory I (Chemical Engrg.) Junior Design Laboratory (Electrical Engrg.) Mechanics Laboratory (Mechanical Engrg.) Decision Analysis (Industrial & Systems Engrg.)

In a strict analysis, we should track the cohort of students who completed the modules shown in Table 9 and analyze their learning. However, the assessment results provided by instructors were anonymous and therefore we could not track the performance of specific students. The overall EML Index computed through Eq. 4 therefore reflects the achievement of KSOs in an average sense for all students who completed the courses shown in Table 9 in Fall 2017 and Spring 2018. The overall EML Index for all 18 KSOs achieved by students taking courses with the four integrated e-learning modules listed in Table 9 are shown in Figure 15. The maximum values that could have been achieved by students are shown as black bars. None of the four modules covered the “Customer,” “Societal,” “S_Chain” and “IP” KSOs, hence the EML Index related to these KSOs is zero. In general, the integrated e-learning modules are effective in developing an EM in students. Through further discussions with instructors and enhancement of the contextual activities deployed in the courses to reinforce what students learn from the e-learning modules it is possible to improve student learning and their EM.

We will continue to analyze data from other courses as they become available so that we can assess the impact of all 18 e-learning modules on the EM of our students as they approach graduation.

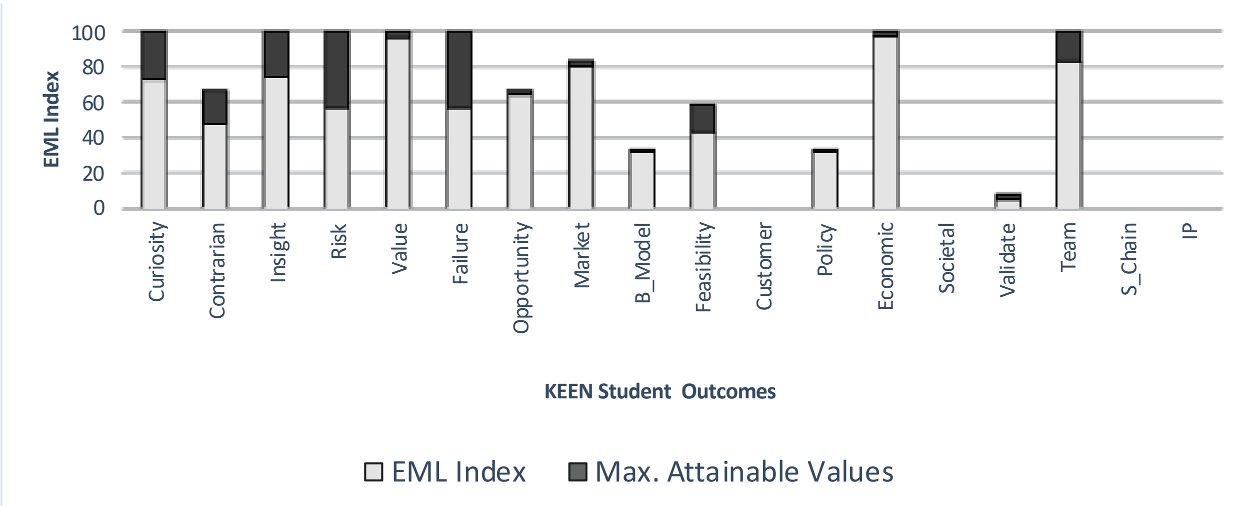

Figure 15. Overall EML Index for students completing the TC, LFF, CoP and ET modules

Conclusions

Three indices are proposed to measure student achievement of 18 KEEN student outcomes (KSOs) by completing courses with integrated e-learning modules that cover entrepreneurial topics: (1) the Module Specific EML Index, $I_{k,m}$, that is a measure of the average student achievement of KSO *k* by completing integrated module *k*; (2) the Module Specific EML Effectiveness Index, $E_{k,m}$, that is a measure of how well students learned about KSO *k* on average through integrated module *k*; and (3) the overall EML Index, I_k, that is a measure of the average student achievement of KSO *k* by completing multiple integrated modules. These indices are based on instructor ratings of student performance on assessment outcomes specific to each module, and a mapping showing the depth of how well each direct assessment outcome relates to the KSOs.

The Module Specific EML Index is an effective measure of how well students learn the 18 KEEN student outcomes (KSOs) from one of the e-learning modules that are integrated into a course. Students learn content not only from the e-learning module, but also from the contextual activities that the instructor uses in the course in which students can apply what they learned. The value of the index depends on how well students do on the assessment outcomes specified for each module. Therefore, the instructor should carefully design the contextual activities and be diligent about assessing all of the assessment outcomes.

Low values of the Module Specific EML Effectiveness Index indicate that instructors could potentially improve the integration of an e-learning module to enhance student learning. This is especially true when the same module and integration approach is used across multiple sections of the same course. Comparisons across instructors would be strengthened if inter-rater reliability is enhanced by bringing together all instructors and helping them calibrate on a uniform set of expectations for the assessment. When instructors did not assess all the

assessment outcomes for each module, the values of the EML Effectiveness Index for their courses were significantly lower than that for instructors who assessed all outcomes.

The overall EML Index is an effective measure of the impact of the comprehensive curricular intervention of integrating multiple e-learning modules into several courses. It provides a way of assessing learning across multiple modules and courses. Because the performance of students from all courses and sections that use a module are included in the computation of the index, variability across instructors are averaged out, yielding more reliable results.

Acknowledgments

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Appendix: Examples of Contextual Activities for Select Modules

Faculty were trained to develop and implement one or more contextual activities in their courses so that students could apply what they learned in the e-learning modules. The contextual activities varied by institution and/or faculty, and some were stronger than others. The contextual activities for the *Thinking Creatively* and *Elevator Pitch* module integrations that are reported in this paper are briefly described below. More detailed examples are available in the Instructor Guide related to each module [5].

Thinking Creatively

1. <u>Institution M03 (all instructors):</u> Design a puzzle having a specific theme with a target audience, age group and time to completion. Pieces should interlock so that the puzzle is self-supported when assembled. No fasteners (screws, pins, springs, etc.) may be used. The puzzle must be easy to ship. Engage customers to develop the concept. Evaluate the puzzle concept by conducting a customer survey. Use KT Decision Analysis to choose the optimal design. Fabricate the puzzle using a 3-D printer. Write a technical memorandum summarizing process and findings.
2. <u>Institution M04:</u> Reuse, repurpose, and/or recycle an existing theme park attraction or space to improve guest satisfaction and happiness while increasing park revenue and profitability. Must reuse, repurpose and/or recycle from seven different attractions spaces. Developed proposals and pitch them to the class using NABC (Need, Approach, Benefits/Costs, and Competition) elevator pitches.
3. <u>Institution D03:</u> Identify a feasible capstone design project in response to an industrial or societal need, write a problem statement, state technical challenges involved, propose solution methodologies, state the desired outcomes, then give a presentation in class and answer questions. Complete the following tasks: a) use ideation techniques to generate project ideas; b) perform literature search to check feasibility and identify technical challenges; c) use divergent convergent thinking to generate solution ideas; and d) use comparative evaluation of alternatives to converge on the final selection.
4. <u>Institution D09:</u> Select a project and briefly describe its goal. Explain the problem you are solving and the solution(s) you created. Provide the link to the electronic portfolio for your project. Define creativity. Describe the creative aspects of your project. Explain the source(s) of your creativity for completing your project. Discuss the divergent-convergent thinking process. Explain how you used this process to develop your solution. Discuss the ideation techniques you used to determine your solution.

Elevator Pitch

1. <u>Institution B03:</u> Design, build, test, and document a product that supports the adaptive technology lending library at Reach Services, Inc. (formerly the United Cerebral Palsy organization). The lending library is a collection of adaptive toys and support products that are used by children, parents, and educators as part of curricula designed by rehabilitation

specialists, as well as more casually for individualized purposes of entertainment as well as education. You will support the lending library at Reach Services by developing an adaptation of an existing product (toy or game). You will deliver an elevator pitch to the public about your project.

2. Institution D02: Refine and validate your idea for a drone that will have a pro-social impact. Your deliverables at the end of the course are twofold: a) A minimum viable product for your drone; and b) a 6 minute pitch (presentation) to convince the relevant stakeholders to adopt your idea.
3. Institution D07: Deliver an elevator pitch on your product idea: Your pitch should be geared towards investors. Remember you only have between 60-90 seconds to get our attention. After you complete your pitches (as a group) you will be required to comment (as individuals) on every group pitch.