Full Paper: Assessment of Entrepreneurial Mindset Coverage in an Online First Year Design Course

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Background

At Arizona State University (ASU), we seek to institutionalize Entrepreneurial Mindset (EM) instruction in each ABET-accredited program. EM was operationalized as 17 behavior outcomes, which are intended to be taught across four years of the undergraduate curriculum in at least three required courses: one during the first-year, another during the sophomore or junior year, and a third in the senior Capstone Design course. Program leaders needed a way to assess the extent to which each is covered throughout the undergraduate curriculum. This paper outlines a simple but effective rubric for guiding faculty in implementing EM in a first-year, project-based design course. We are unaware of a similar approach to determining coverage of target outcomes. This paper explains the rubric and demonstrates its application using ASU's EM behavior indicators.

Literature Review

Before assessing the effectiveness of an innovation, program evaluators must determine that the innovation was effectively implemented (Carroll et al., 2007; Durlak, 1998). Carroll et al. argue: "It has been demonstrated that the fidelity with which an intervention is implemented affects how well it succeeds" (Carroll et al, 1998, p. 1). Dulak points out that "[i]mplementation is not an all-or-none construct but exists in degrees along a continuum, from 0% to 100%" (Durlak, p. 7). Nevertheless, quantifying the quality and dosage of implementation can be difficult, and research literature on the subject is sparse. Barry and Ohland assessed the extent to which coverage of the ABET ethics student outcome criterion (3f: an understanding of professional and ethical responsibility) in coursework affected students' scores on the National Council of Examiners for Engineering and Surveying (NCEES) Fundamentals of Engineering (FE) Examination. Determining the dosage of ethics coursework was done through faculty interviews. The researchers found a relationship between coursework and the exam outcomes, but the method by which coverage of ethics was quantified is not provided (Barry, 2009; Barry & Ohland, 2012). Even during the ABET program review process, no guidelines are provided to help evaluators assess coverage of program and student criteria (ABET, 2013).

The framework devised to assess coverage of EM behavioral outcomes is designed to promote specificity in faculty members' judgements about the *mode* by which an EM behavior is taught and the *extent* to which it is covered. The rubric is built on the assumption that students learn least from lecture and readings, they learn more by doing, and that assessment drives student learning (Freedman et al., 2014; Gibbs, 1999). Felder & Brent note: "Mastery of a skill comes mainly from doing things, noticing and reflecting on the results, and possibly getting feedback from someone else" (Felder & Brent, 2016, p.3). We understand that the assumption underlying the rubric will not hold in all cases in all courses. We reason, however, that the target EM behaviors are performance-based and therefore can only be internalized through practice. Therefore, weighting skill development over lecture is appropriate. We reason that assessment increases impact. Gibbs (1999) argues that "assessment is the most powerful lever teachers have to influence the way students respond to courses and behave as learners" (p. 41). Grades raise

the stakes of student learning, particularly when assessment is preceded by skill development, which increases reinforcement of target outcomes (Biggs, 1999; Irons, 2007).

Methods

At ASU, the entrepreneurial mindset has been operationalized into 17 outcome behaviors (London et al., 2018--see Table 1).

Table 1: ASU EM Behavioral Outcomes*

a. Critically observes surroundings to recognize opportunity
b. Explores multiple solution paths
c. Gathers data to support and refute ideas
d. Suspends initial judgement on new ideas
e. Observes trends about the changing world with a future-focused orientation/perspective
f. Collects feedback and data from many customers and customer segments
g. Applies technical skills/knowledge to the development of a technology/product
h. Modifies an idea/product based on feedback
i. Focuses on understanding the value proposition of a discovery
j. Describes how a discovery could be scaled and/or sustained, using elements such as revenue streams, key partners, costs, and key resources
k. Defines a market and market opportunities
l. Engages in actions with the understanding that they have the potential to lead to both gains or losses
m. Articulates the idea to diverse audiences
n. Persuades why a discovery adds value from multiple perspectives (technological, societal, financial, environmental, etc.)
o. Understands how elements of an ecosystem are connected
p. Identifies and works with individuals with complementary skill sets, expertise, etc.
q. Integrates/synthesizes different kinds of knowledge

**Adapted from London et al., 2018, p. 7.*

To map these 17 outcomes into a framework that provides teachable content in a first-year engineering design course, a rubric was devised to help faculty plan modules that incorporate EM goals by categorizing the 17 behaviors into eight Topic Areas. This rubric is designed for a first-year, project-based design course only and may not be suitable for upper level technical courses. The eight topic areas include; Opportunity Identification, Customer Discovery, Evaluating Solutions, Ideation, Rapid Prototyping, Design Iteration, Potential Value Evaluation, and Market Factors.

Table 2: EM Topic Area to Behavioral Outcome Correlation

EM Topic Area	EM Behavioral Outcome
Problem Identification	a, e, i
Customer Discovery	b, d, e, f, i, k
Evaluating Solutions	b, c, d
Ideation	b, c, d, l

Rapid Prototyping	g, h, q
Design Iteration	c, h, l
Potential Value Evaluation	e, i, j, k, m, n, o
Market Forces	e, i, j, k, n, o

*Topic Area "p", not categorized above, focuses on teamwork, which is extensive in the first-year design course and is therefore covered throughout.

Based on coverage of each Topic Area, we rated each (a-q) EM outcome as to the *mode(s)* by which it was covered: *Introduced, Developed Skills*, and/or *Assessed*. Within each mode, the *extent* of coverage is determined to be either minimal, moderate, or extensive. In the *Introduced* mode, material can be covered either minimally or moderately. In Developed Skills and Assess modes, topics are covered either moderately or extensively (see Table 3).

Table 3: EM Coverage Mode and Level EM Implementation

	EXTENT OF COVERAGE			
MODE OF COVERAGE	**Introduce**	Minimal	Moderate	
	Develop Skills		Moderate	Extensive
	Assess		Moderate	Extensive

Introducing a topic at a minimal level might involve a generic overview in class lecture, while a moderate level entails more depth and/or an outside reading, video, or other resource. Once students begin hands-on experiences with a topic or EM outcome, the extent of coverage increases to moderate or extensive, depending on the time, energy, and focus on the concept throughout the course. For example, practicing Customer Discovery as part of a 20-minute class exercise would be considered moderate coverage. An out-of-class (ungraded) requirement to interview 10 potential customers might be considered extensive.

Assessment in this rubric is defined as some graded deliverable that enables a faculty member to determine whether 70% of students achieved 70% proficiency. We instituted this guideline because many faculty were considering a topic to have been assessed if students simply handed in an assignment, without a level of performance being evaluated. Moderate or extensive assessment can be determined based on the extent of effort required and the weight of the grade relative to the entire course.

A summary of the Coverage Rubric for all course Topic Areas can be found in Appendix A. A sample of the overall rubric is provided in Table 4 to show the detail of content encouraged for instructional implementation within "Customer Discovery."

Table 4: Rubric for Customer Discovery Topic Area

Introduce	**Minimal Coverage** Introduce topics such as: Customer discovery vs. product development	**Moderate Coverage** Teach approaches such as: Interviewing protocols Survey best practices

	Users/payers/influencers Introducing ways to learn from customers (surveys/interviews/observations) Overview of human-centered design definition (discover/ideate/prototype/evaluate) Writing requirements based on customer needs Criteria definition based on customer wants	Contextual observations Research from reliable vs. questionable sources POV statements Customer archetypes Ranking criteria based on customer wants
Develop Skills	**<u>Moderate Coverage</u>** Identify users/payers/influencers Identify customer needs Define requirements and criteria based on customer information Evaluate importance of customer wants Identify a POV/archetype profile	**<u>Extensive Coverage</u>** Identify users/payers/influencers Identify customer needs Define requirements and criteria based on customer information Conduct interviews, observations, or surveys Synthesize customer findings to explore value propositions Evaluate importance of customer wants based on customer input Identify a POV/archetype profile
Assess	**<u>Moderate Coverage</u>** Distinguish between users/payers/influencers for a given application Distinguish between customer needs versus wants Prioritize criteria based on customer wants Provide a POV/archetype profile for sample customer	**<u>Extensive Coverage</u>** Define users/payers/influencers for an opportunity Write appropriate requirements and criteria based on customer information Prioritize criteria based on customer input Provide a POV/archetype profile for customer Supply human-centered background information based on student conducted interviews, observations, or surveys Articulate value propositions based on student-led customer discovery methods (interviews/observation/surveys)

Results

Topic Area Coverage Rubric was applied to assess EM coverage in a 15-week, online, first year design course. Overall results can be found in Table 5. This course introduces various engineering design related concepts, tools, and skills, and provides students with opportunities to apply, document, and reflect on what they learn. Each week concepts are introduced through videos from instructors and industry professionals and/or upper division engineering students who talk about how the weekly topic is applied in their work, as well as readings, tutorials, and discussion boards, ePortfolio reflections, a content mastery quiz, and a project deliverable. The course topics are applied in a 5-week, open-ended project in which students develop a conceptual design for an opportunity that they identified, and a 10-week systems-based disaster relief project, in which students design an aircraft to help with disaster scenarios such as wildfires,

hurricanes, tornadoes, earthquakes, and a zombie apocalypse. More details about this online course can be found in Mertz et al., 2018.

Table 5: EM Coverage in the Online First-Year Design Course

EM Topic Areas	***Opportunity Identification***	***Customer Discovery***	***Evaluating Solutions***	***Ideation***	***Rapid Prototyping***	***Design Iteration***	***Potential Value Evaluation***	***Market Factors***
Introduce	Minimal	Moderate	Moderate	Moderate	Moderate	Moderate	Minimal	Minimal
Develop Skills	Extensive	Extensive	Moderate	Extensive	Extensive	Extensive	Moderate	Moderate
Assess	Extensive	Extensive	Moderate	Extensive	Extensive	Extensive	Moderate	Moderate

In this course, Topic Areas are *Introduced* through video lectures. Students *Develop Skills* mainly through two design projects and in activities/discussion boards. Various forms of *Assessment* are used, including content mastery quizzes, ePortfolio reflections, project deliverables, and the final exam. The content mastery quizzes and final exam contain multiple choice, true/false, or fill-in-blanks types of questions. In the ePortfolio reflections, students document and reflect on their newly gained skills, focusing on how the skills were applied in course activities and projects. Project deliverables for the open-ended project include a problem definition deliverable that describes the opportunity that they identified through customer discovery and a final deliverable in the form of slides (with notes) that could be used as a part of a presentation about their final conceptual designs. For the disaster relief project, students submit project memos for subsystems involved in the aircraft design as well as a final design report.

As an example, the introduction of the topic area Customer Discovery in this course is done through a series of videos that discuss the differences between customer discovery/development and product development, and the importance of interviews to customer discovery; introduce concepts including human-centered design, the three-fold division of customer, and requirements versus criteria; and teach approaches such as creating customer archetypes, writing point of view or POV statements, conducting customer interviews, and performing trade studies to evaluate criteria based on customer feedback. Students apply these skills in both projects by identifying stakeholders, users, and payers, as well as user needs, either through the analysis of customer statements and Q & A's or based on student-conducted customer interviews. In each case, students create customer archetypes, write POV statements, identify value propositions, define requirements and criteria based on customer discovery, and rank criteria based on their importance to the customer. These skills are assessed in various project deliverables, in which students provide detailed descriptions, analyses, results and discussions related to customer discovery for their design opportunities.

Summary

This paper outlines a rubric devised for the purpose of assessing coverage of EM topics and providing implementation guidelines for the EM framework, which is operationalized at ASU in the form of 17 behavioral outcomes, to faculty teaching a first-year, project-based design course.

This rubric was devised to help faculty plan modules to better incorporate EM goals and assess EM coverage by categorizing the 17 behaviors into fully formed topic areas. In the rubric, three modes of EM implementation for each topic area are defined, including *Introduce*, *Develop Skills*, and *Assess*. Extent of topic areas are defined as Minimal & Moderate (if *Introduced*), or Moderate & Extensive (if *Skills are Developed* or topic is *Assessed*). An example of EM coverage using this rubric in an online, first year design course was presented and discussed. Though the rubric focuses on EM coverage, it provides a means to reliably determine coverage of any topic or outcome, including ABET student and program outcomes.

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Appendix A. Full Rubric of EM Instructional Content for the Eight Topic Areas

The table below shows the full rubric of EM instructional content for each topic area at each coverage level.

Table A1: Rubric for the Eight EM Topic Areas

Opportunity Identification		
Introduce	**Minimal Coverage** Introduce topics such as: Problem statements Customers and stakeholders Wants vs. needs Value proposition statements	**Moderate Coverage** Teach approaches such as: Scenarios instead of problem definitions Customer opinions Bug List methods Customer Pain Point identification
Develop Skills	**Moderate Coverage** Critique current applications to explain what problem was solved with opportunity/solution Identify problem statements from context provided in stakeholder statements, scenarios, observed issues (faculty directed) Justify proposed opportunities	**Extensive Coverage** Conduct research into stakeholder statements, scenarios, observed issues in order to identify problem statements (open-ended, non-directed) Justify proposed opportunities Articulate the potential generic value created (why is this important to solve?)
Assess	**Moderate Coverage** Analyze a case study (faculty directed context) to identify the problem statement Identify a problem versus a solution Communicate a value proposition statement Link proposed opportunities to specific references	**Extensive Coverage** Communicate an appropriate problem statement from student analysis of open-ended scenario Communicate a value proposition statement Communicate background information gathered regarding proposed opportunity/scenario Link background information to proposed opportunities to show need
Customer Discovery		
Introduce	**Minimal Coverage** Introduce topics such as: Customer discovery vs. product development Users/payers/influencers Introducing ways to learn from customers (surveys/interviews/observations) Overview of human-centered design definition (discover/ideate/prototype/evaluate) Writing requirements based on customer needs Criteria definition based on customer wants	**Moderate Coverage** Teach approaches such as: Interviewing protocols Survey best practices Contextual observations Research from reliable vs. questionable sources POV statements Customer archetypes Ranking criteria based on customer wants

Develop Skills	**Moderate Coverage** Identify users/payers/influencers Identify customer needs Define requirements and criteria based on customer information Evaluate importance of customer wants Identify a POV/archetype profile	**Extensive Coverage** Identify users/payers/influencers Identify customer needs Define requirements and criteria based on customer information Conduct interviews, observations, or surveys Synthesize customer findings to explore value propositions Evaluate importance of customer wants based on customer input Identify a POV/archetype profile
Assess	**Moderate Coverage** Distinguish between users/payers/influencers for a given application Distinguish between customer needs versus wants Prioritize criteria based on customer wants Provide a POV/archetype profile for sample customer	**Extensive Coverage** Define users/payers/influencers for an opportunity Write appropriate requirements and criteria based on customer information Prioritize criteria based on customer input Provide a POV/archetype profile for customer Supply human-centered background information based on student conducted interviews, observations, or surveys Articulate value propositions based on student-led customer discovery methods (interviews/observation/surveys)
Evaluating Solutions		
Introduce	**Minimal Coverage** Introduce topics such as: Rules of brainstorming Categorizing ideas against requirements Comparing solutions against criteria	**Moderate Coverage** Teach approaches such as: Brainstorming techniques Trade studies Decision matrix How to communicate/collaborate with a customer throughout design process
Develop Skills	**Moderate Coverage** Generate multiple design options Conduct trade study comparisons of solutions to find the best fit for customer needs	**Extensive Coverage** Generate multiple design options Conduct trade study comparisons of solutions to find the best fit for customer needs Solicit feedback from customers regarding initial design options Apply feedback to justify trade study scoring
Assess	**Moderate Coverage** Provide multiple design solutions differing in form, function, and finish Provide evidence of a trade study comparison based on customer provided	**Extensive Coverage** Provide multiple design solutions differing in form, function, and finish Provide evidence of a trade study comparison based on customer provided

	criteria	criteria Provide evidence of customer collaboration and feedback regarding initial design options Explain how customer feedback influenced decision-making
Ideation		
Introduce	**Minimal Coverage** Introduce topics such as: Brainstorming Techniques Ideation Methods Introducing Scenarios with opportunities for radical change Showing examples of engineering in unconventional industries/solutions	**Moderate Coverage** Teach approaches such as: Brainstorming techniques Ideation methods
Develop Skills	**Moderate Coverage** Apply brainstorming/ideation techniques to form multiple ideas Identify the source of the problem from multiple perspectives	**Extensive Coverage** Apply brainstorming/ideation techniques to form multiple ideas Identify the source of the problem from multiple perspectives Justify why proposed ideas are unique and radical in nature Analyze ideas for feasibility of implementation and impact on customer
Assess	**Moderate Coverage** Provide examples of current solutions that differed from traditional solutions in at least one unique way. Generate ideas to solve a problem with at least one unique feature different from current approaches.	**Extensive Coverage** Provide examples of current solutions that differed from traditional solutions in at least one unique way. Generate ideas to solve a problem with at least one unique feature different from current approaches. Provide evidence of comparison between current solutions and student solution justifying uniqueness. Provide evidence of analysis of advantages versus disadvantages of design options regarding impact on customer, feasibility, function, among other perspectives.
Rapid Prototyping		
Introduce	**Minimal Coverage** Introduce topics such as: Minimum Viable Prototypes Descriptive Modeling techniques Predictive Modeling techniques Rapid design iteration Use just-in-time learning	**Moderate Coverage** Teach approaches such as: Empirical modelling discovery Simulated modelling software Tools for rapid prototype creation Modelling approaches (drawing, behavior, computational, physical)
Develop Skills	**Moderate Coverage**	**Extensive Coverage**

	Create minimum viable prototype Model individual aspects of design solution separately Identify types of appropriate models	Create minimum viable prototype Model individual aspects of design solution separately Identify and apply types of appropriate models to fully describe all aspects of solution Design of experiments to learn outcomes to incorporate into solution Model aspects of solution through simulated software Apply rapid fabrication tools to create early models of prototypes
Assess	**Moderate Coverage** Describe evolution of design through multiple prototypes/models Justify need for models in design Describe purpose of MVP	**Extensive Coverage** Describe evolution of design through multiple prototypes/models Justify need for models in design Describe purpose of MVP Create design of experiment to learn an outcome Use findings from models to iteratively design prototype Describe solution in the form of a variety of model types (simulated, physical)
Design Iteration		
Introduce	**Minimal Coverage** Introduce topics such as: Rapid design iteration Test engineering procedures	**Moderate Coverage** Teach approaches such as: Unit-level testing procedures Troubleshooting methods
Develop Skills	**Moderate Coverage** Identify and learn from failures to improve design Perform rapid iteration of design Test prototypes against requirements and functionality	**Extensive Coverage** Identify and learn from failures to improve design Perform rapid iteration of design Test prototypes against requirements and functionality Implement troubleshooting methods to find faults in design Skill: Write and perform test procedures to verify functionality
Assess	**Moderate Coverage** Describe evolution of design through multiple prototypes/models Describe preliminary testing to find failures Describe design improvements based on testing outcomes	**Extensive Coverage** Describe evolution of design through multiple prototypes/models Describe preliminary testing to find failures Describe design improvements based on testing outcomes Write testing procedures to verify functionality Perform testing procedures to find failures Evaluate cause and effect of failure and

		suggest improvement Implementation of design improvements through design lifecycle
Potential Value Evaluation		
Introduce	**<u>Minimal Coverage</u>** Introduce topics such as: Societal factors Financial analysis Value Proposition Scenario simulations Cause and Effect	**<u>Moderate Coverage</u>** Teach approaches such as: PESTEL analysis SWOT analysis Return-on-investment analysis
Develop Skills	**<u>Moderate Coverage</u>** Create value proposition statement Identify two or more societal perspectives impacted by design Explain basic financial concepts Identify additional market scenarios to apply design solution	**<u>Extensive Coverage</u>** Create value proposition statement Identify three or more societal perspectives impacted by design Explain basic financial concepts Identify additional market scenarios to apply design solution Perform analysis of societal impact from three or more perspectives Evaluate financial feasibility of design Communicate value from individual, micro, and macro perspectives
Assess	**<u>Moderate Coverage</u>** Interpret basic financial concepts Write value proposition statement List and describe different societal perspectives Describe and justify additional market scenarios for design	**<u>Extensive Coverage</u>** Interpret basic financial concepts Write value proposition statement List and describe different societal perspectives Describe and justify additional market scenarios for design Identify strengths and weaknesses of design Categorize positive impact of design based on societal perspectives Identify potential competitors Calculate return-on-investment
Market Factors		
Introduce	**<u>Minimal Coverage</u>** Introduce topics such as: Supply and Demand Finding trends Actions of buyers and sellers Value Proposition Financial Analysis Recognizing competitors	**<u>Moderate Coverage</u>** Teach approaches such as: Online review analysis Return-on-investment analysis Market Research Methods Focus group Contextual Inquiry Crowdsourcing SWOT analysis
Develop Skills	**<u>Moderate Coverage</u>**	**<u>Extensive Coverage</u>**

	Research current trending solutions Create value proposition statement Perform qualitative or quantitative analysis of value (financial, customer demand)	Research current trending solutions Create value proposition statement Perform qualitative or quantitative analysis of value (financial, customer demand) Implement market research methods to learn value proposition
Assess	**<u>Moderate Coverage</u>** Compare features/function against competitor solutions Write value proposition statement Justify value based on financial or customer demand analysis	**<u>Extensive Coverage</u>** Compare features/function against competitor solutions Write value proposition statement Justify value based on financial or customer demand analysis Summarize market research approaches used to learn potential value Explain results and findings from market research Identify opportunities for new market expansion Assess return-on-investment potential