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Development of the Engineering Student Entrepreneurial Mindset Assessment (ESEMA)

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ABSTRACT

The increasing presence of entrepreneurship within many engineering curricula requires a complementary tool to assess the impact on learners. An instrument was developed based on the Kern Entrepreneurial Engineering Network's 3Cs - Curiosity, Connections, and Creation of Value - framework to assess entrepreneurial mindset. The instrument was designed to target twelve total mindsets. Items were pilot tested four times with undergraduate students at a large southwestern public institution. Results in this paper are given for the last of four pilots in Spring 2017. Exploratory factor analysis was utilized to identify the number of emergent factors and overall importance of each item. The ensuing instrument contained 34 items within seven factors. The developed instrument and results of this study provide a foundation to support the accurate assessment of engineering student entrepreneurial mindsets before, during, and after an entrepreneurial experience.

Key words: Entrepreneurship, undergraduate education, factor analysis

INTRODUCTION

There is a need to prepare engineering graduates who can effectively respond to contemporary challenges. This is one reason why an emphasis on design has become a quintessential component of undergraduate engineering education (Froyd, Wankat, & Smith, 2012) and sets engineers apart from science, technology, and mathematics professionals (Dym, Agogino, Eris, Frey, & Leifer, 2005). The engineering design process makes customer needs a focus of decision making, which by extension motivates engineers to create solutions that will address customer needs and provide customer value (Dym et al., 2005). The desire of engineers to create customer-driven solutions has led to a growing interest within engineering education to embed (Kriewall & Mekemson, 2010; Tryggvason, Schauffeld, & Banks, 2010) and examine (Duval-Couetil, Reed-Rhoads, & Haghighi, 2011; Kleine & Yoder, 2011) entrepreneurship. Notably, entrepreneurship also extends the typical engineering design process to consider the creation of infrastructure for scaling and sustainability of the proposed solution, allowing for the greater possibility of developing solutions that have lasting change and impact.

An increasingly common approach to assessing the impact of embedded entrepreneurial activities within engineering curricula is to examine entrepreneurial mindset (EM). One way that EM has been operationalized in engineering education is by the Kern Family Foundation's 3Cs. The Kern Family Foundation is dedicated to supporting efforts that promote EM among engineering students and faculty as demonstrated by the Kern Entrepreneurship Engineering Network (KEEN; 2017). KEEN supports a variety of efforts that foster *Curiosity*, making *Connections*, and *Creation of Value* for others (KEEN, 2017). The 3Cs distinguish EM from entrepreneurship through their emphasis on the mindsets necessary to create personal, societal, *and* economic value rather than the actual process of creating a business venture (http://engineeringunleashed.com/keen/about/). Scholarship is currently underway to more clearly operationalize The 3Cs into an EM framework (e.g., London et al, 2018).

This work utilizes ongoing research to develop a theoretically supported EM assessment instrument. Clarifying our terms and how we are assessing them puts the engineering education community in a better position to situate our work within the realm of entrepreneurial activity. The subsequent sections of this paper include the process we used to develop an instrument to assess EM among undergraduate engineering students and the items that make up the ensuing instrument. This paper closes with a discussion of the resultant factors and next steps.

METHODS

Instrument Overview

The Engineering Student Entrepreneurial Mindset Assessment (ESEMA) is a self-report measure of undergraduate engineering students' EM. The instrument is grounded in the framework for entrepreneurial mindsets and behaviors presented in London et al. (2018). This framework intentionally used The 3Cs as a starting point for defining the constructs underlying EM and was refined based on multiple rounds of reviewing the relevant EM literature. The final framework includes twelve total mindsets (London et al., 2018). While we acknowledge that other frameworks may have also been applicable to the development of the ESEMA, a specific goal was to more clearly define and operationalize The 3Cs through concepts found in existing research. We anticipate such an instrument to be of interest to two groups – first, researchers and educators within KEEN who are interested in understanding how The 3Cs relate to other scholarship in the area, and second, others outside of KEEN who study EM and who may be interested in what members of a network fully dedicated to this topic are doing.

In the ESEMA, we consider a mindset to be a mental attitude, idea, or disposition held by an individual that impacts their response to and interpretation of a situation (Dweck, 2006). The instrument includes both positively and negatively worded items. Respondents to the instrument are asked to "Think about your past experiences … and respond by indicating how true each of the following statements are to you." Response options are arrayed on a five-point Likert scale (Nunnaly & Bernstein, 1994) which includes as options 1 ("never or only rarely true of me"), 2 ("sometimes true of me"), 3 ("true of me about half the time"), 4 ("frequently true of me"), and 5 ("always or almost always true of me").

Item Generation and Face Validation

Items for the ESEMA were generated from literature on entrepreneurship, EM, and engineering education (e.g., Abdulwahed, Hamad, Hasanain, & Hasna, 2013; Bodnar, Clark, & Besterfield-Sacre, 2015; Duval-Couetil et al., 2011). Item development was carried out by a research team of five engineering education faculty. An initial set of 60 items was written or modified from existing surveys (e.g., Auzmendi, Villa, & Abedi, 1996; Sheppard et al., 2010; Wakabayashi et al., 2006); 29 were written to measure Curiosity, 10 for Connections, and 21 for Creation of Value. Face validity was assessed using a focus group of undergraduate engineering students who were asked to identify items that were unclear and to suggest modifications. Items identified as confusing were revised to improve clarity.

Exploratory Factor Analysis

An iterative examination of the factor structure for the preliminary instrument was conducted following item generation. The instrument was first administered to first and second-year engineering students at a large, public institution in the southwestern region of the U.S. four times between June 2016 and February 2017. Exploratory factor analysis was conducted after each deployment. Changes were made between each administration of the survey. The data and findings presented here represents the last of four pilots, administered in Spring 2017.

Table 1. Participant sample demographics (n = 259).

Gender	Male	64%
	Female	35%
Race/Ethnic Identification	White	50%
	Hispanic/Latino	16%
	Asian	15%
	American Indian or Alaska Native	1%
	Black/African American	< 1%
	Multiracial	12%
	All others	4%
Undergraduate Engineering Major	Mechanical Engineering	20%
	Computer Science	14%
	Electrical Engineering	9%
	Biomedical Engineering	8%
	Aerospace Engineering	8%
	Civil, Environmental & Sustainable Engineering	8%
	All others	33%
Exposure to Starting Own Business through …	Parents/guardians	28%
	Siblings	5%
	Other relatives	32%
	Other friends or contacts	30%
	Themselves	7%

Participants and Procedures. To recruit for the study, a survey invitation and reminders were sent to all 2,600 first-year engineering students. Participants anonymously completed an online version of the ESEMA along with a demographic questionnaire. Participants had the option at the end of the survey to enter a random drawing for one of ten $20 Amazon gift cards. A total of 259 students submitted complete responses, yielding a 10% response rate. Demographics of the sample are shown in Table 1. Seventy percent of the participants reported knowing someone who started their own business; parents/guardians, relatives other than siblings or parents/guardians, and friends accounted for the most exposure.

Analysis Approach

An exploratory factor analysis (EFA) was conducted using SPSS to reduce the items into a smaller number of more interpretable factors. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test for sphericity (McCoach, Gable, & Madura, 2013) were used to investigate the appropriateness of factor analysis on the data. Parallel analysis was then used to determine the appropriate number of factors to extract (Slocum-Gori & Zumbo, 2011).

Principal axis factoring (PAF) was used for factor extraction. Unlike other factor extraction techniques, PAF accounts for both measurement error and sampling error (McCoach et al., 2013). The promax oblique rotation was used to optimize factor loadings based on the assumption that there was likely to be some correlation between factors. Our process adopts the recommendations by McCoach et al. (2013) and retained items on a factor if they loaded at 0.4 or above on that factor and 0.3 or below on all other factors. Negatively worded items were reverse-scored prior to analysis.

The factor structure was considered acceptable when all items met loading requirements, inter-item correlations were statistically significant, factor correlations were less than 0.85, and all factors had at least two items along with internal consistency estimates considered acceptable for affective instruments (McCoach, et al., 2013). The choice of allowing two-item factors may be considered non-traditional, as it is known that more items typically lead to better representation of a construct and better reliability. Per Yong and Pearce (2013), we chose to allow two-item factors with highly correlated items to represent as many as possible of the constructs from the London et al. (2018) framework. Cronbach's alpha (Cronbach, 1951) was used for factors with three or more items to determine internal consistency. The Spearman-Brown coefficient was used for two-item factors (Eisinga, Grotenhuis, & Pelzer, 2013).

RESULTS

The KMO analysis (KMO value = 0.865) and the Bartlett's test ($p < 0.000$) suggested that the items of the ESEMA were factorable, and results of the parallel analysis supported the retention of seven factors. A total of 34 items, organized into seven factors, were retained after removing items with low or cross-loadings. The resulting instrument and factor structure can be found in Appendix 1. The corresponding factor loadings are shown in Table 2.

The largest retained factor is Ideation, which includes nine items that measure enjoyment in generating of ideas and challenging the status quo and one item that measures persistence through setbacks. An eight-item factor measuring appreciation of, and willingness to work with, individuals with different expertise was retained and named Open-Mindedness. An Interest factor was retained; this factor has three items that measure an inherent interest in a variety of things. An Altruism factor was retained; this factor also has three items and measures an interest in making a positive contribution to the world. Two two-item factors were retained and named Empathy and Help Seeking. Empathy measures appreciation of others' perspectives and viewpoints. Help Seeking measures a willingness to seek out help when necessary. The final factor contained seven

Table 2. ESEMA factor structure and factor loadings.

Item	Factor Loading	Item	Factor Loading
Factor 1: Ideation		**Factor 4: Altruism**	
Id-1	0.708	A-21	0.717
Id-2	0.659	A-22	0.650
Id-3	0.650	A-23	0.539
Id-4	0.613	**Factor 5: Empathy**	
Id-5	0.573	E-24	0.683
Id-6	0.542	E-25	0.704
Id-7	0.526	**Factor 6: Help Seeking**	
Id-8	0.498	HS-26	0.708
Id-9	0.427	HS-27	0.686
Factor 2: Open-Mindedness		**Factor 7: Unnamed**	
OM-10	0.769	U-28	0.636
OM-11	0.684	U-29	0.620
OM-12	0.657	U-30	0.513
OM-13	0.599	U-31	0.513
OM-14	0.541	U-32	0.504
OM-15	0.532	U-33	0.451
OM-16	0.475	U-34	0.431
OM-17	0.451		
Factor 3: Interest			
In-18	0.810		
In-19	0.782		
In-20	0.684		

* Note: Numbering aligns with items presented in Appendix 1.

negatively worded items related to a variety of constructs, including risk taking and willingness to pivot on an idea. The research team did not believe that these items converged around an interpretable construct and as a result remained unnamed. Cronbach's alphas for factors with three or more items ranged from 0.71 to 0.84. Spearman-Brown correlations for factors with two items ranged from 0.55 to 0.68.

The correlations between items within each factor were found to be statistically significant at level $p < 0.05$ for five factors and level $p < 0.010$ for two factors. Messick (1995) suggests that this indicates evidence of convergent validity, discounting the likelihood that alternative constructs would better explain the data. Additionally, factor correlations ranged from 0.04 to 0.53 (not exceeding the 0.85 cut-off), providing evidence in support of divergent validity.

DISCUSSION AND CONCLUSIONS

Our design of an instrument to measure the EM of engineering students was informed by a new framework based on The 3Cs (London et al., 2018). Efforts to design items around the framework's twelve mindsets revealed seven emergent factors from our exploratory factor analysis. Six of the seven factors were identified as Ideation, Open-Mindedness, Interest, Altruism, Empathy, and Help Seeking; the final factor was unnamed.

Examining the items within each factor suggests that some mindsets stand alone while others combine within and across The 3Cs. The four mindsets that stand alone are Interest, Altruism, Empathy, and Help Seeking. These factors align with specific mindsets from the London et al. (2018) framework – "inherent interest in a wide variety of things" and "empathetic to the perspectives and viewpoints of others", which are mapped in the framework to Curiosity; "awareness of one's own limitations", which is mapped to Connections; and "motivation to make a positive contribution", which is mapped to Creation of Value. These factors similarly align with efforts to incorporate different aspects of EM into engineering curricula, such as curiosity (Zappe & Yoder, 2017) and empathy (Korte, Smith, & Li, 2017).

Open-Mindedness and Ideation are factors that include items designed for multiple mindsets. Open-Mindedness consists of items targeting three mindsets within the EM framework – "appreciation for different disciplinary knowledge and skills" and "a willingness to work with individuals with different skill sets, expertise, and disciplines", which are mapped in the framework to Connections, and "willingness to change direction on an idea", which is mapped to Creation of Value. These three mindsets together reveal an appreciation of and willingness to work with individuals of different expertise. The set of items comprising Ideation focuses primarily on challenging or creatively generating new ideas, but also includes an item from "persistence through setbacks and willingness to overcome failure".

The seventh emergent factor was a combination of negatively worded items that the research team did not feel was meaningfully interpretable. Recent studies have shown that negatively worded items can often load together even after being reverse-scored and should be positively worded to align with current best practices (McCoach et al., 2013). Adopting this approach will allow us to examine the possibility of newly emergent factors, which could address currently missing mindsets present in the EM framework.

Overall, the resulting instrument helps fill a need for a measure that assesses the EM of undergraduate engineering students based on an underlying framework. The intention of the instrument is for use by engineering programs to either provide a base understanding of the mindsets students are bringing to an engineering program or inform how activities meant to impact students' EM should be designed. For example, instructors aiming to promote Curiosity among their students could design activities specifically meant to encourage interest in a variety of things, empathy toward other people, and ideation.

LIMITATIONS & FUTURE WORK

The design and development of the instrument was guided using the EM framework presented by London et al. (2018), but neither The 3Cs nor the mindsets included in the framework emerged from our exploratory factor analysis. Several mindsets overlapped within and across The 3Cs making it difficult to support each mindset's existence and inclusion (e.g., Ideation). A seventh factor contained all negatively worded items, which will need to be modified in future work to investigate the possibility of newly emergent factors. At the same time, mindsets within the London et al. (2018) framework were organized based on beliefs about how they would group across Cs. The mindsets themselves were based in extant research, and it is therefore unsurprising that the resulting factors correspond to other constructs within the EM literature. Future work could explore the utility of a revised framework in which these factors, rather than the mindsets, are mapped to The 3Cs (for example, Interest and Empathy mapped to Curiosity, Ideation and Altruism to Creation of Value, and Open Mindedness and Help Seeking to Connections).

The instrument is now being disseminated to broader populations of undergraduate engineering students, including those who may have more exposure, experience, or training with EM than first-year and second-year students. This dissemination process will be used to conduct further tests of validity and reliability on the instrument, including confirmatory factor analysis, the results of which will be published in future journal articles. Separately, modifications to the instrument to remove a purely negatively worded factor are underway. Further studies are needed to determine whether a revised instrument can reveal pre-post changes characteristic of a growth mindset.

REFERENCES

Abdulwahed, M., Hamad, J. A., Hasanain, M., & Hasna, M. O. (2013). Entrepreneurship education in engineering: A literature review and an integrated embedment proposal. *Recent Advances in Educational Methods, 12*(5), 106–111.

ABET. (2010). Criteria for accrediting engineering programs *Effective for evaluations during the 2011–2012 accreditation cycle.* Baltimore, MD: ABET.

Auzmendi, E., Villa, A., & Abedi, J. (1996). Reliability and validity of a newly constructed multiple-choice creativity instrument. *Creativity Research Journal, 9*(1), 89–95.

Bodnar, C. A., Clark, R. M., & Besterfield-Sacre, M. (2015). Lessons learned through sequential offerings of an innovation and entrepreneurship boot camp for sophomore engineering students. *The Journal of Engineering Entrepreneurship, 6*(1), 52–67.

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrica*, 16, 297–334.

Duval-Couetil, N., Reed-Rhoads, T., & Haghighi, S. (2011). The engineering entrepreneurship survey: An assessment instrument to examine engineering student involvement in entrepreneurship education. *The Journal of Engineering Entrepreneurship, 2*(2), 35–56.

Dweck, C. (2006). *Mindset: The new psychology of success.* New York, NY: Ballantine Books.

Eisinga, R., Grotenhuis, M. T., & Pelzer, B. (2013). The reliability of a two-item scale: Pearson, Cronbach, or Spearman-Brown? *International Journal of Public Health*, 1–6.

Kern Engineering Entrepreneurship Network (KEEN). (2017). *Entrepreneurial Mindset 101.* Accessed from, http://engineeringunleashed.com/keen/em101/.

Kleine, R. E. & Yoder, J-D. (2011). Operationalizing and assessing the entrepreneurial mindset: a rubric based approach. *The Journal of Engineering Entrepreneurship, 2*(2), 57–86.

Korte, R., Smith, K., & Li, C. (2017). The Entrepreneurial Mindset and the role of empathy in opportunity discovery. Prepared for *Advances in Engineering Education* Special Issue on Entrepreneurial Mindset.

Kriewall, T. J. & Mekemson, K. (2010). Instilling the entrepreneurial mindset into engineering undergraduates. *The Journal of Engineering Entrepreneurship, 1*(1), 5–19.

London, J. S., Bekki, J. M., Brunhaver, S. R., Carberry, A. R., & McKenna, A. F. (2018). A framework for entrepreneurial mindsets and behaviors in undergraduate engineering students, in preparation for *Advances in Engineering Education.*

McCoach, D. B., Gable, R. K., & Madura, J. P. (2013). *Instrument development in the affective domain*. New York, NY: Springer.

Messick, S. (1995). Validity of psychological assessment. *American Psychologist*, 50(9), 741–749.

Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometrics theory* (3rd ed.). New York: McGraw-Hill.

Sheppard, S., Gilmartin. S., Chen, H. L., Donaldson, K., Lichtenstein, G., Eris, O., Lande, M., & Toye, G. (2010). *Exploring the engineering student experience: Findings from the Academic Pathways of People Learning Engineering Survey (APPLES).* Seattle, WA: Center for the Advancement for Engineering Education.

Slocum-Gori, S. L., & Zumbo, B. D. (2011). Assessing the unidimensionality of psychological scales: Using multiple criteria from factor analysis. *Social Indicators Research*, 102(3), 443–461.

Tryggvason, G., Schaufeld, J. J., & Banks, M. C. (2010). Teaching engineering innovation and entrepreneurship early in the curriculum. *The Journal of Engineering Entrepreneurship, 1*(1), 42–50.

Wakabayashi, A., Baron-Cohen, S., Wheelwright, S., Goldenfeld, N., Delaney, J., Fine, D., Smith, R., & Weil, L. (2006). Development of short forms of the Empathy Quotient (EQ-Short) and the Systemizing Quotient (SQ-Short). *Personality and Individual Differences, 41*(5), 929–940.

Zappe, S., & Yoder, J. D. (2017). Defining and assessing curiosity in the context of entrepreneurship education. Prepared for *Advances in Engineering Education* Special Issue on Entrepreneurial Mindset.

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APPENDIX 1

ESEMA Instrument

Factor 1: Ideation (Id)

1. I like to reimagine existing ideas
2. I like to think about ways to improve accepted solutions
3. I typically develop new ideas by improving existing solutions
4. I like to think of wild and crazy ideas
5. I tend to challenge things that are done by the book
6. Other people tell me I am good at thinking outside the box
7. I prefer to challenge adopted solutions rather than blindly accept them
8. I tend to see my ideas through even if there are setbacks
9. I look for new things to learn when I am bored

Factor 2: Open-Mindedness (OM)

10. I am willing to consider an idea put forth by someone with a different background than my own
11. I am willing to compromise if another idea seems better than my own
12. I appreciate the value that different kinds of knowledge can bring to a project
13. I appreciate the value that individuals with different strengths bring to a team
14. I recognize that people with different backgrounds from my own might have better ideas than I do
15. I am willing to learn from others who have different areas of expertise
16. I recognize the importance of other fields even if I don't know much about them
17. I am willing to update my plans in response to new information

Factor 3: Interest (In)

18. I tend to get involved in a variety of activities
19. I enjoy being involved in a variety of activities
20. I participate in a wide range of hobbies

Factor 4: Altruism (A)

21. The idea of tackling society's biggest problems does not motivate me (reverse scored)
22. I believe it is important that I do things that fix problems in the world
23. I am driven to do things that improve the lives of others

Factor 5: Empathy (E)

24. I can easily tune into how someone else feels
25. Other people tell me I am good at understanding their feelings

Factor 6: Help Seeking (HS)

26. I know when I need to ask for help
27. I am comfortable asking others for help

Factor 7: Unnamed (U)

28. I prefer what I am used to rather than what is unfamiliar (reverse scored)
29 I would rather work with what is familiar than what is unfamiliar (reverse scored)
30. I am less likely to change directions on a project after putting forth a lot of effort (reverse scored)
31. I tend to resist change (reverse scored)
32. I like to work on problems that have clear solutions (reverse scored)
33. I prefer tasks that are well-defined (reverse scored)
34. I tend not to do something when I am unsure of the outcome (reverse scored)