2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
ASEE
Paper ID #38466

Survey of the Entrepreneurial Mindset of Students in Undergraduate Laboratory Courses

Akshara Subramaniasivam
Dr. Rebecca Marie Reck, University of Illinois at Urbana - Champaign

Rebecca M. Reck is a Teaching Associate Professor of Bioengineering at the University of Illinois Urbana-Champaign. Her research includes alternative grading, entrepreneurial mindset, instructional laboratories, and equity-focused teaching. She teaches biomedical instrumentation, signal processing, and control systems. She earned a Ph.D. in Systems Engineering from the University of Illinois Urbana-Champaign, an M.S. in Electrical Engineering from Iowa State University, and a B.S. in Electrical Engineering from Rose-Hulman Institute of Technology.

Prof. Katie Ansell, University of Illinois, Urbana-Champaign

Katie Ansell is a Teaching Assistant Professor of Physics at the University of Illinois, Urbana-Champaign. Her teaching and research activities focus on the practical and social aspects of the classroom that contribute to the development of student expertise in Introductory Physics Laboratories.

Prof. Holly M. Golecki, University of Illinois at Urbana - Champaign

DDr. Holly Golecki (she/her) is a Teaching Assistant Professor in Bioengineering at the University of Illinois Urbana-Champaign and an Associate in the John A Paulson School of Engineering and Applied Sciences at Harvard University. She holds an appointment at the Carle-Illinois College of Medicine in the Department of Biomedical and Translational Sciences. She is also a core faculty member at the Institute for Inclusion, Diversity, Equity, and Access in the College of Engineering. Holly studies biomaterials and soft robotics and their applications in the university classroom, in undergraduate research and in engaging K12 students in STEM. Holly received her BS/MS in Materials Science and Engineering from Drexel University and her PhD in Engineering Sciences from Harvard University.

Chandrasekhar Radhakrishnan
Dr. Christopher D. Schmitz, University of Illinois at Urbana - Champaign

Christopher D. Schmitz received his Ph.D. in Electrical and Computer Engineering from the University of Illinois in 2002.

Dr. Jessica R. TerBush, University of Illinois at Urbana - Champaign

Jessica received her B.S.E, M.S.E., and PhD in Materials Science and Engineering from the University of Michigan, Ann Arbor. After graduation, she worked as a post-doc for approximately three years at Monash University in Clayton, Victoria, Australia. She then spent three years working as a Senior Research Specialist at the Missouri University of Science and Technology in Rolla, Missouri, where she trained users on the focused ion beam (FIB), scanning electron microscope (SEM), and transmission electron microscope (TEM). In 2016, she moved to the University of Illinois, Urbana-Champaign, to serve as a lecturer in the department of Materials Science and Engineering. Here, she is responsible for teaching the junior labs as well as providing instruction on writing in engineering.

Survey of Entrepreneurial Mindset of Students in Undergraduate Laboratory Courses

Introduction

Undergraduate laboratories are a key part of the curriculum in STEM fields. Many of the objectives of these laboratories' experiences overlap with Kern Entrepreneurial Engineering Network's (KEEN) Entrepreneurial Mindset (EM) framework. KEEN's EM framework includes learning outcomes related to curiosity, connections, and creating value (3C's) [1]. In the 2022-23 academic year, a team of laboratory and design course instructors at a large public university in the Midwestern United States began to explore this overlap and surveyed students enrolled in the laboratory courses about various aspects of the framework. This work-in-progress paper illustrates the overlap between the framework and undergraduate laboratory courses and presents the initial student survey results. The initial analysis shows similar results to previous surveys at other institutions implementing the framework.

Entrepreneurial Mindset and Laboratory Courses

Laboratories are key learning spaces in undergraduate STEM programs. They bridge the gap between theory and practice whilst engaging students in experiments and active learning. Learning in a laboratory consolidates scientific and engineering concepts to develop engineering design abilities, enable problem-solving and nurture professional and social skills [2]. The undergraduate laboratory is important in preparing students for practice beyond the university. Skills developed in the laboratory, such as conducting experiments and tests, solving problems, designing, and innovating, are key skills for professional practice. In the last two decades, laboratories have been further enhanced by the introduction of the digital computer and systems of distance learning, particularly over the Internet [3]. The digital computer has opened new possibilities in the laboratory with updated software and hardware capabilities, increasing access to global information and instant communication.

Laboratory programs can help students develop an entrepreneurial mindset by providing opportunities for them to think creatively and develop innovative solutions to real-world problems. Through hands-on experience in the laboratory, students are exposed to the process of designing, prototyping, and testing innovative ideas, similar to the process of developing new products in industry. Laboratories mimic the cohesive integration of social, institutional, and cultural environments, both at the individual level and the group level which entrepreneurship aims to bring about. Considering the importance of laboratory instruction in science, design and engineering, there has been relatively little attention paid to assessing the overlap of the learning objectives of STEM laboratory courses in the entrepreneurial mindset framework. This overlap is explored in detail in Table 1 by mapping the engineering laboratory objectives previously described [3] to the learning objectives associated with the KEEN's EM Framework [1]. We found that all learning objectives from laboratories overlap with the objectives from the EM framework. While the laboratory objectives are more detailed and map to multiple EM objectives, both have an objective for learning from failure. Given this significant overlap, applying lessons from the EM Framework in laboratory courses may improve the attainment of laboratory objectives as well [4].

Table 1 - Overlap between engineering laboratory objectives and KEEN's Entrepreneurial Mindset Framework

	KEEN Entrepreneurial Mindset Framework Objectives					
	Curiosity [5]		**Connections** [6]		**Creating Value** [7]	
Laboratory objectives [3]	**Demonstrate constant curiosity…**	**Explore a contrarian view …**	**Integrate information from many sources…**	**Assess and manage risk.**	**Identify opportunities to create … value**	**Persist through & learn from failure**
Instrumentation. Apply appropriate sensors, instrumentation, and/or software to make measurements…			x			
Models. Identify the strengths and limitations of theoretical models as predictors of real-world behaviors.			x			
Experiment. Devise an experimental approach, specify appropriate equipment and procedures, implement these procedures, and interpret the resulting data…	x	x				x
Data Analysis. Demonstrate the ability to collect, analyze, and interpret data, and to form and support conclusions.			x		x	
Design. Design, build, or assemble a part, product, or system, including using specific methodologies, equipment, or materials; meeting client requirements…	x		x	x	x	x
Learn from Failure. Identify unsuccessful outcomes…						x
Creativity. Demonstrate appropriate levels of independent thought, creativity, and capability in real-world problem solving.	x	x				
Psychomotor. Demonstrate competence in selection, modification, & operation of engineering tools…	x		x			
Safety. Identify health, safety, and environmental issues related to technological processes and activities, and deal with them responsibly.				x	x	
Communication. Communicate effectively about laboratory work with a specific audience…		x			x	
Teamwork. Work effectively in teams…	x		x		x	
Ethics in the Laboratory. Behave with highest ethical standards…				x	x	
Sensory Awareness. Use the human senses to gather information…	x		x			

Assessment of Entrepreneurial Mindset
In this paper, we assess the impact of embedded entrepreneurial activities within undergraduate laboratory courses by examining the student's entrepreneurial mindset (EM). This work utilizes a theoretically supported EM assessment instrument: The Engineering Student Entrepreneurial Mindset Assessment (ESEMA) [8] to understand if the student's perception of the skills and attributes learned in a laboratory course aligned with the EM framework. 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 [1] and was developed based on the Kern Entrepreneurial Engineering Network's 3Cs - Curiosity, Connections, and Creation of Value [1].

Methods
This study explores the overlap between the objectives of undergraduate laboratory and project-based courses and the KEEN Entrepreneurial Mindset framework. After the fall 2022 semester, we surveyed students about their mindset after completing a laboratory or design course at our institution. The purpose of this phase of the study was to pilot an existing instrument to determine if it would be a useful assessment in our courses. The details of the data collection, context of the courses, and analysis are described below.

Data Collection
With IRB approval, after the fall 2022 semester, students enrolled in one of seven project-based or laboratory-based courses were invited to complete the survey in Qualtrics. The survey included demographic information, the 32 items from the ESEMA [8], and some additional questions for teamwork study conducted by the same team. Upon completion of the survey, students were offered the opportunity to enter a drawing for a $25 Amazon gift card (1 card per 100 respondents). Instructors from the respective courses sent email invitations at the beginning of the spring 2023 semester and students were given approximately two weeks to complete the survey. Approximately 1530 students received email invitations. Additionally, instructors who sent the survey were asked to complete a short form providing additional context about their course to include in this study.

A total of 109 students submitted complete responses, yielding a 7% response rate. Demographics of the sample are shown in Table 2. Sixty eight 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. Most of the gender and race demographics align with the demographics of the college of engineering except for the representation of bioengineering which is one of the smaller departments. This is likely due to the affiliation of the faculty involved in this project.

Table 2 - Participant Sample Demographics (n=109)

Gender	Male	56%
	Female	37%
	Non-binary/ Third gender	5%
	Did not specify	2%
Race/Ethnic Identification	White	44%
	Hispanic/Latino	6%
	Asian	45%
	American Indian	2%
	Alaska Native	1%
	Black/African American	< 1%
	All others	2%
Undergraduate Engineering Major	Bioengineering	37%
	Electrical & Computer Engineering	27%
	Materials Science & Engineering	11%
	Mechanical Science & Engineering	5%
	Aerospace Engineering	5%
	Physics	3%
	Civil & Environmental Engineering	2%
	Industrial & Enterprise System Engineering	2%
	Other	7%
Exposure to Starting Own Business through ...	Parents/guardians	14%
	Siblings	5%
	Other friends & relatives	21%
	Coursework	11%
	Internship or Work Experience	14%
	Personal (you have started a business of your own)	4%
	None	31%

Course Context

The instructors are all members of a community of practice (CoP) of lab and design instructors in the College of Engineering [9]. The goal of the CoP is to share knowledge about what has been successful in courses and collectively identify solutions for similar challenges. Since the College has recently become a member of the KEEN partner, the focus of the 2022-23 academic year for the CoP was exploring ways to incorporate one of the 3Cs in our courses. The changes ranged in from no changes to slight modifications of lecture content to adding new assignments. The context of each course is described in Table 3, below.

Table 3 – Fall 2022 Course Details

Course ID	Description	Year	Approximate Enrollment	Required / Elective	EM Activity
BIOE 100	A one credit, project-based bioengineering course	1	118	Required	Yes, Assignment: Create the ABCs of BIOE
BIOE 303	Bioengineering laboratory course	3	54	Required	No
BIOE 415	Bioengineering laboratory course	3 & 4	27	Required	Yes, Lecture topic: learning from failure and feedback to revise work
ECE 110	Electronics hybrid course with a combination of lectures and laboratory work	1	450	Required	Yes, Assignment: team contracts and reflections
ECE 343	Electronics laboratory course	3 & 4	100	Elective	Yes, Lecture topic: introduced lab exercises to encourage integration of experiences across related courses to explore new solution spaces of an engineering problem
MSE 307	Material science & engineering hybrid course with a combination of lectures, group & laboratory work	3	59	Required	Yes, Lecture topic: Tied lab experiments to real world examples to show value and make connections between theory and application)
PHYS 212	A hybrid course with a combination of lectures, discussions & laboratory work	1 & 2	700	Required	Yes, Assignment: team contracts and reflections

Data Analysis

A maximum-likelihood factor analysis was conducted using R 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 [10] were used to investigate the appropriateness of factor analysis on the survey data in [8]. The appropriate number of factors to be extracted was chosen by a series of significance hypothesis tests for the chosen factors.

A maximum-likelihood factor analysis was used for factor extraction. The promax oblique rotation was used to optimize factor loadings based on the assumption that there was likely to be some correlation between factors. The process mostly adopts the recommendations by Brunhaver, et. al., [10] and retains items on a factor if they are loaded at 0.3 (recommended 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 [10]. Even though two-item factors are considered non-traditional and feeds to poor representation and readability, our study does allow two-item factors similar to [8] with highly correlated items to represent as many as possible of the constructs from the KEEN Entrepreneurial mindset framework [1].

Results and Discussion

The KMO analysis and Bartlett's test suggested that the items of the survey assessment were factorable. A series of significance hypothesis tests for the chosen factors supported the retention of seven factors out of which one factor was eventually dropped because its overall factor loading was less than 0.3. A total of 32 items, organized into six factors, were retained after removing items with low or cross-loadings. The resulting instrument, factor structure and their corresponding factor loadings are shown in Table 4, below.

Table 4 - The factor structure and their respective loadings

Factor structure	Loadings
Factor 1: Ideation	
1. I like to reimagine existing ideas	**0.746**
2. I like to think about ways to improve accepted solutions	**0.705**
3. I typically develop new ideas by improving existing solutions	**0.54**
4. I like to think of wild and crazy ideas	**0.689**
5. I tend to challenge things that are done by the book	**0.56**
6. Other people tell me I am good at thinking outside the box	**0.543**
7. I prefer to challenge adopted solutions rather than blindly accept them	**0.497**
8. I tend to see my ideas through even if there are setbacks	**0.465**
9. I look for new things to learn when I am bored	**0.54**
Factor 2: Open-Mindedness	
10. I am willing to consider an idea put forth by someone with a different background than my own	**0.397**
11. I am willing to compromise if another idea seems better than my own	**0.781**
12. I appreciate the value that different kinds of knowledge can bring to a project	**0.456**
13. I appreciate the value that individuals with different strengths bring to a team	**0.543**
14. I recognize that people with different backgrounds from my own might have better ideas than I do	**1.012**
15. I am willing to learn from others who have different areas of expertise	**0.7**
16. I am willing to update my plans in response to new information	**0.55**
Factor 3: Interest	
17. I tend to get involved in a variety of activities	**0.77**
18. I enjoy being involved in a variety of activities	**0.76**
19. I participate in a wide range of hobbies	**0.42**
Factor 4: Altruism	
20. I believe it is important that I do things that fix problems in the world	**0.734**
21. I am driven to do things that improve the lives of others	**0.651**
Factor 5: Empathy and Help Seeking	
22. I can easily tune into how someone else feels	**0.398**
23. Other people tell me I am good at understanding their feelings	**0.300**
24. I know when I need to ask for help	**0.719**
25. I am comfortable asking others for help	**0.835**

Factor 6: Unnamed	
26. I prefer what I am used to rather than what is unfamiliar (reverse scored)	**0.692**
27. I would rather work with what is familiar than what is unfamiliar (reverse scored)	**0.382**
28. I am less likely to change directions on a project after putting forth a lot of effort (reverse scored)	**0.395**
29. I tend to resist change (reverse scored)	**0.43**
30. I like to work on problems that have clear solutions (reverse scored)	**0.332**
31. I prefer tasks that are well-defined (reverse scored)	**0.253**
32. I tend not to do something when I am unsure of the outcome (reverse scored)	**0.875**

Conclusions and Future Work

In this study we identified a significant overlap between the learning objectives of undergraduate STEM laboratory courses and KEEN's entrepreneurial mindset (EM) framework. To evaluate this overlap, we used an existing instrument, ESEMA [8] developed to support the assessment of engineering student entrepreneurial mindsets before, during, and after an entrepreneurial experience. Our initial analysis, which attempted to reduce our survey items into a smaller number of more interpretable factors, proved to be similar to previous studies even though our target population was different. Five out of six of our factors almost identically matched the factor loadings proposed by ESEMA further bolstering the impact of undergraduate STEM laboratory courses in developing an entrepreneurial mindset in students.

Next, we plan to compare courses with and without intentional EM activities to assess the difference in response for each factor. Similar to our factors, 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 [10]. Adopting this approach before administering the survey in the spring semester of 2023 will allow us to examine the possibility of newly emergent factors, which could address currently missing mindsets present in the EM framework. As this was a small pilot study with the existing instrument, future work also includes adding more EM related activities to existing laboratory and design courses and using an updated assessment tool to compare the mindset of students in laboratory and design courses across the college. We plan to increase the survey response rate with multiple reminders and additional incentives for Spring 2023.

References

[1] KEEN, "The Framework," *Engineering Unleashed*, 2022. https://engineeringunleashed.com/framework (accessed Apr. 28, 2022).

[2] C. Winberg and S. L. Winberg, "The role of undergraduate laboratories in the formation of engineering identities: A critical review of the literature," *The Journal for Transdisciplinary Research in Southern Africa*, vol. 17, no. 1, Art. no. 1, Apr. 2021, doi: 10.4102/td.v17i1.962.

[3] L. D. Feisel and A. J. Rosa, "The Role of the Laboratory in Undergraduate Engineering Education," *Journal of Engineering Education*, vol. 94, no. 1, pp. 121–130, 2005.

[4] Jennifer M. Bekki, Mark Huerta, Jeremi S. London, Doug Melton, Margot Vigeant, and Julia M. Williams, "OPINION: Why EM? The Potential Benefits of Instilling an Entrepreneurial Mindset - AEE Advances in Engineering Education," *AEE*, vol. 7, no. 1, Accessed: Feb. 28,

2023. [Online]. Available: https://advances.asee.org/opinion-why-em-the-potential-benefits-of-instilling-an-entrepreneurial-mindset/

[5] Doug Melton, “CURIOSITY: What do we mean?,” *KEEN Cards, Engineering Unleashed*, Aug. 25, 2021. https://engineeringunleashed.com/card/1493 (accessed Mar. 09, 2022).

[6] Doug Melton and Joe Tranquillo, “CONNECTIONS: What do we mean?,” *KEEN Cards, Engineering Unleashed*, Aug. 25, 2021. https://engineeringunleashed.com/card/1448 (accessed Mar. 11, 2022).

[7] Bill Kline and Doug Melton, “CREATING VALUE: What do we mean?,” *KEEN Cards, Engineering Unleashed*, Aug. 25, 2021. https://engineeringunleashed.com/card/670 (accessed Mar. 11, 2022).

[8] S. R. Brunhaver, J. M. Bekki, A. R. Carberry, J. S. London, and A. F. McKenna, “Development of the Engineering Student Entrepreneurial Mindset Assessment (ESEMA),” *Advances in Engineering Education*, vol. 7, no. 1, 2018, Accessed: Apr. 28, 2022. [Online]. Available: https://advances.asee.org/development-of-the-engineering-student-entrepreneurial-mindset-assessment-esema

[9] R. Reck, K. Ansell, J. TerBush, C. Schmitz, J. Popovics, and H. Golecki, “Development of a Community of Practice for Rethinking Best Practices in Post-COVID Experiential Learning,” presented at the 2022 ASEE Annual Conference & Exposition, Aug. 2022. Accessed: Feb. 13, 2023. [Online]. Available: https://peer.asee.org/development-of-a-community-of-practice-for-rethinking-best-practices-in-post-covid-experiential-learning

[10] D. B. McCoach, R. K. Gable, and J. P. Madura, *Instrument Development in the Affective Domain: School and Corporate Applications*. New York, NY: Springer, 2013. doi: 10.1007/978-1-4614-7135-6.