Synthesizing Definitions of Professional Competencies Linked to Experiential Learning in Engineering Education: A Literature Review

Cassandra Sue Ellen Woodcock
University of Michigan

John Callewaert
University of Michigan

Joanna Millunchick
University of Michigan

Experiential learning has been linked to improved outcomes for students in higher education. In engineering, experiential learning is viewed as highly aligned with the pedagogy of engineering education, however, consensus on which outcomes are relevant and how they are defined has not been established. This literature review explores how engineering education literature has defined a set of twelve competencies linked to experiential learning in engineering. A synthesis of literature defining Communication, Creativity, Empathy, Entrepreneurial Mindset, Ethics, Global and Cultural Awareness, Grit / Persistence / Resilience, Leadership, Lifelong Learning, Ability to Accept and Manage Risk, Systems Thinking, and Teamwork is presented.

INTRODUCTION

Experiential learning opportunities have been described as important in higher education contexts for many years (Itin, 1999) as these opportunities have been linked to better career placement and recruitment and retention efforts (Cantor, 1995). Experiential learning opportunities have been identified as a key pedagogical feature of engineering education leaders in recent reports like one from MIT titled The Global State of the Art in Engineering Education (Graham, 2018). Perhaps this emphasis stems from experiential education's alignment with engineering design education efforts (Harrisberger & others, 1976), its potential to support the development of professional competencies (Fisher, Bag, & Sarma, 2017; Simmons, Creamer, & Yu, 2017), or its ability to produce more innovative, career-ready engineers (Conger et al., 2010).

Students frequently engage in experiential learning at our institution, particularly in the College of Engineering, however, we found that the intentionality regarding development and measurement of professional competencies was limited in these efforts (J. Callewaert, 2019; J. Callewaert, Millunchick, Woodcock, Jiang, & Edington, 2020). Similar issues regarding measuring the impact of experiential learning efforts in engineering education more broadly have been documented (Chan, 2012; Johnson & Main, 2020). To begin to address these concerns at our institution, we sought to identify, define, and curate resources to measure a set of professional competencies relevant across experiential learning contexts in

engineering. As such, we performed a literature review to explore the way these competencies have been measured and defined previously. This work was performed as part of the College of Engineering's strategic vision initiative and will be referred to as the Experiential Learning Framework (ELF) for the remainder of this paper.

BACKGROUND

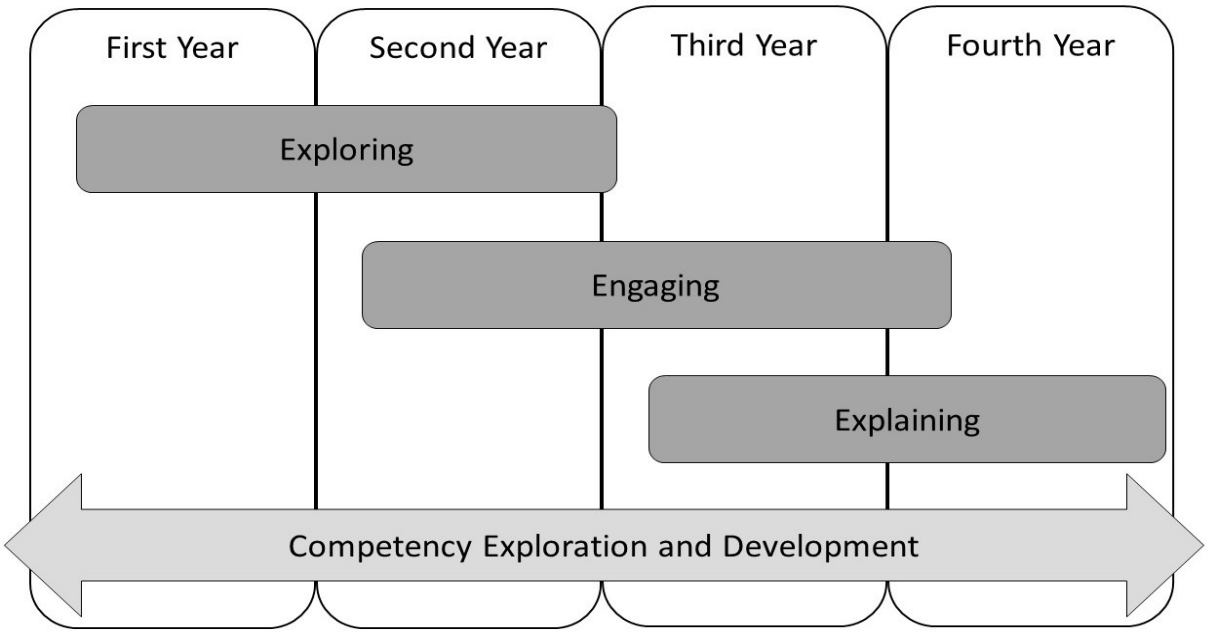
Value of Experiential Learning in Engineering

We define experiential learning in line with the conceptualization put forth by Kolb (Kolb & Kolb, 2009; Kolb, 1984, 2015; Kolb, Boyatzis, & Mainemelis, 2011) who describes a process where learners move through four interconnected stages: concrete experience (CE), reflective observation (RO), abstract conceptualization (AC), and active experimentation (AE) (Kolb et al., 2011). Kolb's work has been popularly used in higher education contexts, and was informed by the work of other scholars like Kurt Lewin, John Dewey, and Jean Piaget (Kolb, 2015). This conceptualization of experiential learning is aligned with many scholars' descriptions that also demonstrate a four stage process of learning. These conceptualizations of experiential learning focus on changes in judgement, knowledge, or skills (i.e. development of competencies) as a result of living through an event (Itin, 1999). Experiential education, which is highly related to experiential learning has aimed to formalize the educational process by which students engage in experiential learning (Itin, 1999; Luckmann, 1996). These targeted efforts to incorporate experiential learning in education often emphasize opportunities to interact with the teacher, take risks and make mistakes, and reflect on the experience as key features of experiential education. Experiential learning initiatives that have been identified in educational literature span a broad scope and can include: active learning, adventure education, field work experiences, games, inquiry-based learning, internships, lab work, outdoor education, previous work experience, problem-based learning, project-based learning, service learning, simulations, student-directed learning, vocational education, etc. (Itin, 1999; Morris, 2019). Within engineering, experiential learning opportunities have been emphasized as an essential piece of engineering education (Conger et al., 2010; Duderstadt, 2008; Graham, 2018), and can include activities such as participation in engineering design and competition teams, professional and honors societies, or scientific research. However, broad definitions of experiential education have created a need for a strategy to assess the impact of experiential learning that is similarly broad and adaptable to multiple contexts. Our literature review is a first step towards that strategy.

Introduction to the Experiential Learning Framework (ELF)

ELF is an approach to support student engagement in experiential learning as well as the flexible and robust assessment of student development through experiential learning under development in the College of Engineering at our institution. Frameworks in education literature are often used as a structured strategy for developing a study or interpreting data collected within a study (Green, 2014). Our use of the term framework, in this case, denotes the broad, overarching goal of expanding access to and impact of experiential learning rather than developing a specific explanation for how students engage or how it should be assessed. The key goals as we develop ELF has been to help students intentionally explore learning opportunities, meaningfully engage in experiences, iteratively reflect on their learning, and clearly communicate their development of one or more key professional competencies (see FIGURE **1**). We believe the goals of ELF are strongly aligned with conceptualizations of the experiential learning process as defined by Kolb (Kolb & Kolb, 2009; Kolb, 1984, 2015; Kolb et al., 2011). As a first step in the development of ELF, it was necessary to identify key professional competencies linked to experiential learning opportunities and then describe them based on scholarly views in engineering education literature. This paper describes our process for selecting and defining professional competencies through a systematized literature review (Grant & Booth, 2009). While we explored these competencies to inform our work on ELF relevant to the College of Engineering at our institution, we believe the insights from our review benefit the community broadly in understanding and applying the many interpretations of professional competencies in engineering education literature.

FIGURE 1
VISUAL REPRESENTATION OF STUDENT EXPERIENCE WITH THE EXPERIENTIAL LEARNING FRAMEWORK (ELF)



METHODS

Identification of the Twelve Professional Competencies of Interest

The competencies researched in this paper were identified as important to experiential learning efforts through a synthesis of reports put forth by recent national engineering education efforts (American Society for Engineering Education, 2013; Atman et al., 2010; *Infusing Real World Experiences into Engineering Education*, 2012; National Academy of Engineering, 2005, 2013), multiple leadership groups on our campus (*CoE Strategic Planning Committee - Educational Experience Commission*, 2018; University of Michigan Students, 2019), and the new ABET accreditation criteria released in 2019 (ABET, 2020). Reports from our campus included a report from a committee formed by a strategic vision initiative at the college of engineering called the Educational Experience Commission (EEC) as well as a report by student leaders in the College of Engineering (*CoE Strategic Planning Committee - Educational Experience Commission*, 2018). The EEC was formed in 2018 and charged with considering the idea of requiring College of Engineering graduates to obtain experiential learning credential(s) beyond the technical requirements of their degree. In doing so, they were tasked with exploring the format, measurement, and desired outcomes of experiential learning credentials. Their resulting report detailed a list of nine (9) outcomes of experiential learning participation as well as recommendations for how to implement an experiential learning initiative at the college. Similarly, in 2019, a group of third- and fourth-year student leaders in the College of Engineering investigated experiential learning opportunities at the college. The resulting report also provided recommendations and concerns for implementing experiential learning credentials as well as a list of eight (8) competencies and four (4) goals they thought could be developed through experiential learning engagement (University of Michigan Students, 2019). When developing a list for our literature search, we also considered the newly released ABET accreditation criteria for engineering graduates. TABLE 1 indicates the overlaps we identified and provides context for the specific terms used by each report since each report used slightly different terms. By identifying overlap in the discussions, we determined twelve competencies to explore in our literature search: *Communication, Creativity, Empathy,*

Entrepreneurial Mindset, Ethics, Global and Cultural Awareness, Grit / Persistence / Resilience, Leadership, Lifelong Learning, Ability to Accept and Manage Risk, Systems Thinking, and Teamwork.

TABLE 1
COMPETENCY OVERLAP IDENTIFICATION FROM UNIVERSITY SOURCES AND NEW ABET CRITERIA

Competencies with Overlap	EEC Report	Student Report	ABET Criteria 3[1]
Communication	Communication	Communication	Criteria 3.3
Creativity	Personal Attributes (creativity)	Creativity	
Empathy	Personal Attributes (self-awareness, empathy)	Self-Awareness and Empathy[2]	
Entrepreneurial Mindset	Personal Attributes (entrepreneurial mindset)	Entrepreneurial Mindset[2]	
Ethics	Social, Civic Ethics	Social and Civic Ethics[2]	Criteria 3.4
Global and Cultural Awareness	Global, Cultural Awareness, Cultural intelligence, and skill in working in an environment with people from different backgrounds (cultural, technical, religious, etc.)		Criteria 3.4
Grit, Persistence, Resilience	Personal Attributes (resilience, persistence, initiative)	Initiative Persistence and Resilience	
Leadership	Leadership	Teamwork and Leadership	Criteria 3.5
Lifelong Learning	Personal Attributes (self-reflection) Self-Directed, Independent, Lifelong Learning	Self-Reflection Independent, Lifelong Learning[2]	Criteria 3.7
Ability to Accept and Manage Risk	Ability to Accept and Manage Risk	Risk Management	
Systems Thinking	Systems Thinking (complexity, critical thinking, problem solving in an authentic environment)	Systems Thinking	Criteria 3.2
Teamwork	Teamwork, Collaboration and Relationship Building	Teamwork and Leadership	Criteria 3.5

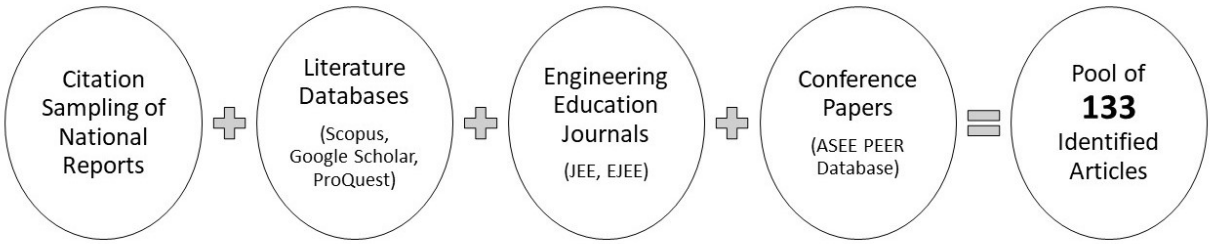
[1]For a full description of the ABET criteria, see APPENDIX 2.
[2]Competencies labelled with a superscript[2] were listed as 'goals' in the student report.

Literature Search

The goal of the systematized literature search performed was to identify the way the competencies of interest to the college were defined and measured in engineering education literature. We wished to understand how literature already discussed the competencies to develop definitions and measurement strategies of each competency. As such, we performed a four-step targeted literature search focusing on the twelve (12) competencies we identified across national and local discussions (see

FIGURE **2** for overview). To establish a pool of articles to review, we first applied a citation search, or snowball sampling strategy (Borrego, Foster, & Froyd, 2014) to the reports used to identify our twelve (12) competencies by searching the citations for article titles that contained any of the competencies of interest. We then used three databases (Scopus, ProQuest, and Google Scholar) to further search for articles. The search was formatted to target articles that described an experiential, co-curricular, or extra-curricular opportunity and sought to measure outcomes related to at least one of the twelve competencies. In the third step, we aimed to target publications in engineering education specific journals and selected two that publish studies with relatively high impact and international scopes (Journal of Engineering Education, JEE, and European Journal of Engineering Education, EJEE). We went directly to the journal's website and searched each competency, pulling articles with the searched competency in the title, abstract, or key words. The final step in the search process was to repeat step three for conference papers published through the American Society of Engineering Education (ASEE). We used the PEER database to search for conference papers with the searched competency in the title. Upon completion of the four-step search, the authors pulled 133 articles that described at least one of the competencies of interest.

FIGURE 2
PROCESS DIAGRAM FOR COMPETENCY ARTICLE IDENTIFICATION



Competency Definition Synthesis

We then reviewed each of the 133 articles, pulling information from 57 of the articles (see TABLE 2) that provided definitions of at least one of the competencies in our review. The remaining articles applied competencies relevant to our study but were not explicit about how they defined the competency and were therefore not used in the synthesis of definitions. Definitions were then compiled by competency in a master document to aid in the definition synthesis process. We then synthesized the information captured in the definitions pulled from the literature search into one sentence definitions.

These one-sentence definitions as well as the process by which they were created were then presented to faculty and staff in two sessions which were part of an experiential learning discussion series organized by the authors and the College of Engineering's Center for Research on Learning and Teaching. The purpose of the sessions was to introduce the competencies to faculty and staff interested in experiential learning and to request feedback on the definitions. In the session, we asked faculty to review the resources pulled for a subset of competencies and discuss in small groups what was captured and what may be missing in the definitions presented. Facilitators in each group took notes on the discussions and faculty were encouraged to also note their thoughts on handouts that contained the definitions and resources.

After collecting and reviewing facilitator and participant notes, we discussed necessary changes to the definitions and found that the competencies may be more thoroughly described using a general definition in conjunction with definitions of multiple sub-constructs. We present the competencies and their sub-competencies in the results.

TABLE 2
RELEVANT LITERATURE REVIEWED THAT PROVIDED DEFINITIONS FOR AT LEAST ONE COMPETENCY IN THE ARTICLE

Competency	Literature reviewed
Communication	(Carter, Ro, Alcott, & Lattuca, 2016; Keshwani & Adams, 2017; Lappalainen, 2009; Ro & Loya, 2015; Wilkins, Bernstein, & Bekki, 2015)
Creativity	(Atwood & Pretz, 2016; Charyton, Jagacinski, Merrill, Clifton, & DeDios, 2011; Charyton & Merrill, 2009; Court, 1998; Daly, Adams, & Bodner, 2012; Daly, Mosyjowski, & Seifert, 2014; Dukart, 2016; Dym, Agogino, Eris, Frey, & Leifer, 2005; Fisher, 2013; Genco, Hölttä-Otto, & Seepersad, 2012; Hallman, Wright, & Conger, 2016; Kusano, Wright, & Conger, 2016; Zheng, Shih, & Mo, 2009)
Empathy	(Hess, Strobel, Pan, & Morris, 2017; Rasoal, Danielsson, & Jungert, 2012; Walther, Miller, & Sochacka, 2017)
Entrepreneurial Mindset	(Bilén, Kisenwether, Rzasa, & Wise, 2005; Gilmartin et al., 2019; Kusano, Wright, et al., 2016; Mcgee, Peterson, Mueller, & Sequeira, 2009; Woodcock, Shekhar, & Huang-Saad, 2019; Yi & Duval-Couetil, 2018)
Ethics	(Burt et al., 2011; Carpenter, Harding, Sutkus, & Finelli, 2014; Colby & Sullivan, 2008; Finelli et al., 2012; Fisher, 2013; Herkert, 2000; Zoltowski, Buzzanell, & Oakes, 2013)
Global and Cultural Awareness	(Bielefeldt, Paterson, & Swan, 2010; Davies, Zaugg, & Tateishi, 2015; Downey et al., 2006; Fisher, 2013; Keshwani & Adams, 2017; Kusano, Conger, & Wright, 2015; Lohmann et al., 2006; May et al., 2015; Rico-garcía & Burns, 2019; Ro & Loya, 2015; Zhang et al., 2015)
Grit, Persistence, Resilience	(Bottomley, 2015; Jaeger, Freeman, Whalen, & Payne, 2010; Lerner, 2013; Morgan, 2018; Verdín, Godwin, Kirn, Benson, & Potvin, 2018)
Leadership	(Ahn, Cox, & London, 2014; Carter et al., 2016; Knight & Novoselich, 2017; Reeve et al., 2015; Ro & Loya, 2015; Simpson, Evans, & Reeve, 2012)
Lifelong Learning	(Kusano, Wright, et al., 2016; Zheng et al., 2009)
Ability to Accept and Manage Risk	(Meertens & Lion, 2008; Woodcock et al., 2019)
Systems Thinking	(Dym et al., 2005; Fordyce, 1988; Seat, Parsons, & Poppen, 2001)
Teamwork	(Carter et al., 2016; Fisher, 2013; Kusano, Conger, & Wright, 2016; Oladiran, Uziak, Eisenberg, & Scheffer, 2011; Ro & Loya, 2015; Zhang et al., 2015)

RESULTS

Competency Definitions

Upon completion of our literature search, synthesis, feedback, and editing process, we determined definitions of the twelve competencies (see TABLE 3), each of which also include between three (3) and four (4) sub-competencies which can be used to further understand the competency definitions. The sub-competencies were added to cover distinct but complementary facets of the competencies and clarify our interpretations of each competency for the readers (see Table 4 for a list of sub-competencies by competency).

TABLE 3
RESULTANT COMPETENCY DEFINITIONS

Competency	Definition
Communication	Ability to critically read, listen, reflect, and convey information effectively in a variety of media with diverse audiences with different needs and perspectives across a variety of settings and contexts.
Creativity	Ability to generate ideas, processes, products that are both novel (unique, original, atypical, cutting-edge) and appropriate (relevant, practical, useful, applicable, fitting, effective).
Empathy	Ability to understand, appreciate, value the perspective of someone else by reasoning from their premises, assumptions, or ideas.
Entrepreneurial Mindset	Ability and intent to engage proactive, innovative strategies in various contexts to solve ambiguous problems.
Ethics	Fully engage stakeholders to recognize that actions and choices have consequences, and that one must act with integrity and trustworthiness.
Global and Cultural Awareness	Ability to acknowledge, practice, and articulate one's own cultural identity to better appreciate, adapt to, and interact with individuals from differing backgrounds, values, and cultures.
Grit, Persistence, Resilience	Ability to persevere and maintain passion/commitment for achievement of long-term goals, despite setbacks, failure, and/or adversity.
Leadership	Cultivating an environment that collectively develops a shared purpose and inspiring others to work toward it.
Lifelong Learning	Ongoing desire and fundamental ability to recognize personal skills/knowledge deficits; seek out and acquire needed skills and knowledge; and continue to grow new interests, talents, and passions.
Ability to Accept and Manage Risk	Ability to critically assess available information, take action despite uncertainty, manage outcomes, and learn from failure as well as from success.
Systems Thinking	Ability to recognize and appreciate the complex structures and their interconnectedness which are embedded in a system while maintaining a view of the highest -level objective to be achieved.
Teamwork	Working to define and achieve a shared goal by leveraging individuals with different perspectives, roles, responsibilities, and aptitudes to overcome and use conflict to their advantage to create a more robust solution.

TABLE 4
COMPETENCIES AND SUBCOMPETENCIES CATEGORIES

Competency	Sub Competencies	
Communication	• Listening • Writing • Presenting – Oral and Visual	• Speaking – Small Group or Informal Settings
Creativity	• Production of Novel Ideas • Production of Useful Ideas • Innovation	• Applying Divergent and Convergent Thinking Processes
Empathy	• Cognitive Empathy • Emotional Empathy	• Empathetic Response
Entrepreneurial Mindset	• Entrepreneurial Skills • Entrepreneurial Intent	• Intrapreneurship

Ethics	• Knowledge of Ethics • Ethical Reasoning	• Ethical Behavior
Global and Cultural Awareness	• Cultural Competence or Awareness • Global Competence or Awareness	• Diverse Workplace Competence or Awareness
Grit, Persistence, Resilience	• Perseverance for Long-Term Goals • Overcoming Setbacks	• Pivoting when Appropriate • Navigating a Hostile Workplace
Leadership	• Team Leadership • Organizational Leadership	• Societal Leadership
Lifelong Learning	• Self-Agency in Educational Choices • Knowing when to Ask for Help	• Ability to Seek out Appropriate Sources to Learn on One's Own
Ability to Accept and Manage Risk	• Recognizing the Need to Take Risks • Consideration of Risk v. Reward in Decision Making	• Being Proactive about Risk Associated with Engineering Work
Systems Thinking	• Ability to Make Appropriate Estimates when Problem Solving • Consideration of the Multi-level Goals of the Project	• Ability to Break Down a System into Discrete Pieces and Put it Back Together in a Coherent Solution
Teamwork	• Recognition of and Commitment to a Common Purpose/Goal • Ability to Work Across Disciplinary Differences	• Valuing the Development of Shared Rules, Norms, Structure

Rubric Development

The sub-competencies were then used to develop competency-specific rubrics aimed at further describing what attainment of that competency would look like at three (3) levels of development (i.e., exploring, engaging, explaining) with exploring being the lowest level and explaining the highest. These labels map to the goal of ELF which is to support students in participating in experiential learning in our college. We envision students who are in an experiential 100 or 200 level course or students who have just joined an experiential out-of-class club or group to participate at an 'exploring' level, students in a 200 or 300 level course or in their first year of an out-of-class club or group to participate at an 'engaging' level, and students in a 300 or 400 level course or have extended participation in an experiential out-of-class club or group to participate at an 'explaining' level. These are general guidelines for where a student might be in attainment of a given competency, however, participation levels may shift based on a students' prior experience in any given competency. The rubric for *Teamwork* has been included as an example in Table 5 and the remaining rubrics can be found in APPENDIX 1.

TABLE 5
EXAMPLE RUBRIC FOR TEAMWORK COMPETENCY

	Exploring (1)	Engaging (2)	Explaining (3)
Valuing the Development of Shared Rules, Norms, Structure	The student makes an effort to understand the norms of the team and follow shared rules but has limited contribution to the development of them.	The student actively engages with the development of shared rules, norms, and team structures and personally follows them.	The student actively engages with the development of shared rules, norms, and team structures and monitors team dynamics with regarding the adherence to them.
Recognition of and Commitment to a Common Purpose/Goal	The student completes their team assigned tasks on time but otherwise is not invested in project completion.	The student completes their team assigned tasks on time and checks with teammates about project goals and progress occasionally.	The student completes their team assigned tasks on time, checks with teammates about project goals and progress, and offers help when necessary.
Ability to Work Across Disciplinary Differences	The student recognizes that working across disciplines is common in engineering practice but cannot articulate the value.	The student recognizes connections between specific project tasks and a given discipline and works to contribute equally.	The student expresses the value of multiple disciplines in solving an engineering problem, and demonstrates an ability to communicate effectively on multidisciplinary teams.

As reflection is a key aspect of experiential learning, we simultaneously developed reflective prompts that aligned with the sub-competencies and three levels of attainment in our rubrics. Reflective prompts were adapted from literature that were part of our described review (Ahn et al., 2014; Daly et al., 2014; Dukart, 2016; Gosselin, Cooper, Lawton, Bonnstetter, & Bonnstetter, 2016; Keshwani & Adams, 2017; Leydens & Lucena, 2010; Walther, Miller, Sochacka, & Brewer, 2016; Zoltowski et al., 2013) as well as from resources provided by an initiative out of the University of Washington called: The Consortium to Promote Reflection in Engineering Education. The group describes the goal of CPREE as, "a larger number of U.S. engineering graduates who are better prepared for the contemporary challenges of the profession." Their website has compiled reflective engineering activities from engineering education institutions across the United States ("Consortium to Promote Reflection in Engineering Education," n.d.). We anticipate our compilation and organization of relevant reflective prompts to be useful for students as they participate in experiential learning at our institution as well as for faculty or administrators wishing to assess development of a competency in students. A full description of the reflective prompts and indicators of performance at a given level of development have been published on our website for public access (J. Callewaert, 2020). An example of reflective prompts and their corresponding indicators for the Teamwork competency can be found in Table 6.

TABLE 6
EXAMPLE OF REFLECTION PROMPTS WITH ATTAINMENT INDICATORS FOR TEAMWORK COMPETENCY

	Exploring (1)	Engaging (2)	Explaining (3)
Valuing the Development of Shared Rules, Norms, Structure	**Q:** Think about a time when you felt [excited, frustrated, impatient, etc.] with your team this semester. Use the following prompts to reflect on that moment in time. 1) What happened? 2) How did it make you feel? 3) How did you interpret it, what role did you play, what role did others play, what caused you to see things differently? 4) If it was a positive experience what would you do in the future to make this happen again, if it was a negative experience what would you do next time to avoid this situation or deal with it better?		
	I: Student demonstrates some reflection on the experience as it relates to the team norms & rules, but does not reflect on their own role in the experience or how it might apply to similar instances in the future.	**I:** Student demonstrates reflection on the experience as it relates to the team norms & rules, and also reflects on either their own role in the experience or how it might apply to similar instances in the future.	**I:** Student demonstrates reflection on the experience as it relates to the team norms & rules, reflects on their own role in the experience, and how it might apply to similar instances in the future.
Recognition of and Commitment to a Common Purpose/Goal	**Q:** How would you define success for your team? In what ways was your team successful? **Q:** What would make collaboration effective for you? For your teammates?		
	I: The student's response is individual focused. They define success (or effective collaboration) in terms of their own actions towards the goal with little focus on the actions of their teammates.	**I:** The student's response focuses on their actions towards the goal of the project, and acknowledges others' contributions.	**I:** The student's response discusses the process of determining team goals, demonstrates their actions towards the goal of the project, and acknowledges others' contributions.
			Q: We have all experienced challenges when working in teams. How might you promote collaboration during group projects to address challenges and concerns that arise? **I:** The student discusses the process used to determine team goals and demonstrates actions they have taken (or would take) if there is disagreement on what the goals are.
Ability to Work Across Disciplinary Differences	**Q:** When might you want to work in a team with engineers from different disciplines? What could be valuable about that experience? What might be difficult?		
	I: The student gives an example of when an	**I:** The student gives an example of when an	**I:** The student gives an example of when an

	engineer might work with different disciplines, but discussion of value or difficulties do not focus on disciplinary differences.	engineer might work with different disciplines and discusses value in terms of tasks/skills/ knowledge associated with various disciplines.	engineer might work with different disciplines and discusses value in terms of communication and collaboration with other disciplines as a means to learn.

Note: 'Q' represents a question posed for students to reflect on while 'I' represents the indicator that a student has reflected at that level for a given sub-competency.

DISCUSSION

In this work, we recognized the importance of experiential learning initiatives in engineering education both as stated by recent reports of engineering leaders (Graham, 2018) and from the various descriptions of its alignment with the goals of engineering (Conger et al., 2010; Fisher et al., 2017; Harrisberger & others, 1976; Simmons et al., 2017); however, we also emphasize the lack of synthesis across research aimed at understanding experiential learning in engineering education. In order to improve students' development of professional competencies and prepare graduates for careers in engineering through experiential learning initiatives, it was first important to understand how engineering educators are defining the competencies we wish to develop. Our review found varied levels of discussion surrounding the competencies we focused on as well as a wide variety of definitions used when describing a competency. Of the articles we identified in our review *Creativity, Ethics,* and *Global and Cultural Awareness* were most frequently defined and discussed in the literature with 8, 7, and 11 articles, respectively. The large number of articles applying and defining these competencies may indicate that many researchers are interested in understanding the development of these competencies in engineering students, however, a larger number of articles defining the competency did not appear to correlate to more consensus on how the competency was defined. This indicated to us the relevance of our work to synthesize definitions across literature in an effort to increase consensus in the field. Conversely, we found very few articles that attempted to define the competencies *Empathy, Lifelong Learning, Ability to Accept and Manage Risk,* and *Systems Thinking* in their work. Our review and synthesis may be particularly relevant for researchers wishing to explore competencies that appear to be fairly new to the engineering education literature.

In an effort better understand competencies in engineering education research, a number of scholars have performed reviews aimed at synthesizing discussions across research in the field. For example, Passow and Passow (2017) performed a review to determine a set of 'generic' engineering competencies across disciplines, their relative importance, and any interrelationships (Passow & Passow, 2017). Their work produced a set of sixteen generic competencies relevant to engineering practice. This work is helpful for researchers interested in general competencies and as such focus more on technical competencies and less on professional competency development. Fisher and colleagues (2017) performed a review to identify competencies that could be developed in out-of-class activities (co-curriculars) creating a framework that detailed potential relationships between development of twenty competencies and involvement in twenty-two categories of co-curriculars (Fisher et al., 2017); however their efforts focused on identifying competencies and where they are perceived to be developed, not how they are defined. Similarly, Simmons, Creamer and Yu also performed a review in 2017 aimed at understanding the extent to which involvement in out-of-class activities impacts ten educational outcomes and found a generally positive association with involvement and development (Simmons et al., 2017). Our review is aligned with these efforts to understand the competencies engineering students develop in their higher education experience; however, our study uses information from reviews like the ones mentioned above to focus on improving consensus for how a subset of competencies are defined in the literature rather than what competencies may be developed in a given context.

Our review addresses a gap in the literature by performing a broadly scoped review of the various ways in which professional competencies linked to experiential learning are defined. We performed this work as

part of the ELF initiative at our institution, however, more broadly, this work serves as a synthesis of the many ways that researchers have defined and conceptualized professional competencies in engineering education research. We provide definitions for each competency that can be used to conceptualize or scope the work of researchers interested in that competency. Additionally, researchers, student group mentors, or administrators may wish to use our review as a tool to quickly explore engineering education literature on a specific competency within the scope of our review. Interested researchers can reference TABLE 2 which details each of the references used to synthesize the one sentence definitions and sub-competency descriptions. We acknowledge that our review was not comprehensive in nature and as such does not claim to incorporate all engineering education literature that defines at least one of the competencies in our study. It also does not address all of the competencies that have the potential to be developed through experiential learning. However, we believe that our work provides value for researchers and institutions wishing to explore student development of professional competencies more intentionally both through the synthesis of the competencies within our review and as a strategy to explore other competencies of interest in the literature. Our work also provides a starting point for how engineering education researchers might begin to build consensus in discussions surrounding engineering student competencies.

CONCLUSION

Upon completion, the ELF will help students identify opportunities for development through experiential learning at the college, structure opportunities to reflect on their experience as a way to develop as an engineering professional, and assist them in communicating what they have learned through the process. As part of the work to assess student development through the ELF, the literature review discussed in this article has informed the creation of reflective prompts and assessment strategies to be implemented in the ELF at our institution. This work documents the strategic efforts to synthesize literature that discusses professional competencies and will inform our ongoing ELF work. It also provides researchers with resources to explore the professional competencies in our review as well as a search and review strategy for exploring competencies outside of the scope of our review.

ACKNOWLEDGMENTS

The authors would like to acknowledge Kevin Jiang (Educational Staff, College of Engineering, University of Michigan); Grenmarie Agresar (Assistant Director, Center for Research on Learning and Teaching in Engineering, University of Michigan); and Tershia Pinder-Grover (Director, Center for Research on Learning and Teaching in Engineering, University of Michigan) for their contributions to the development of ELF and our efforts in sharing work done on its development with other university stakeholders. The authors would also like to thank the faculty, staff, and students who have and continue to provide input on the ELF.

REFERENCES

ABET. (2020). *Criteria for accrediting engineering programs 2019-2020*. Retrieved January 14, 2020, from https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2019-2020/

Ahn, B., Cox, M.F., & London, J. (2014). Creating an Instrument to Measure Leadership, Change, and Synthesis in Engineering Undergraduates. *Journal of Engineering Education*, *103*(1), 115–136. https://doi.org/10.1002/jee.20036

American Society for Engineering Education. (2013). *Transforming Undergraduate Education in Engineering*. National Science Foundation. Arlington Virginia: American Society for Engineering Education.

Atman, C.J., Sheppard, S.D., Turns, J., Adams, R.S., Fleming, L.N., Stevens, R., … Lund, D. (2010). *Enabling Engineering Student Success: The Final Report for the Center for the Advancement of Engineering Education*. San Rafael: Morgan & Claypool Publishers.

Atwood, S.A., & Pretz, J.E. (2016). Creativity as a Factor in Persistence and Academic Achievement of Engineering Undergraduates. *Journal of Engineering Education*, *105*(4), 540–559. https://doi.org/10.1002/jee.20130

Bielefeldt, A.R., Paterson, K.G., & Swan, C.W. (2010). Measuring the value added from service learning in project-based engineering education. *International Journal of Engineering Education*, *26*(3), 535–546.

Bilén, S.G., Kisenwether, E.C., Rzasa, S.E., & Wise, J.C. (2005). Developing and Assessing Students' Entrepreneurial Skills and Mind-Set. *Journal of Engineering Education*, *94*(2), 233–243.

Borrego, M., Foster, M.J., & Froyd, J.E. (2014). Systematic literature reviews in engineering education and other developing interdisciplinary fields. *Journal of Engineering Education*, *103*(1), 45–76. https://doi.org/10.1002/jee.20038

Bottomley, L. (2015). Assessing the GRIT of Incoming Engineering Students. In *American Society for Engineering Education Annual Conference & Exposition* (pp. 26.248.1-26.248.8). https://doi.org/10.18260/p.23588

Burt, B.A., Carpenter, D.D., Finelli, C.J., Harding, T.S., Sutkus, J., Holsapple, M., … Ra, E. (2011). Outcomes of engaging engineering undergraduates in co-curricular experiences. In *American Society of Engineering Education Annual Conference*. https://doi.org/10.1371/journal.ppat.1002091

Callewaert, J. (2020). *Experiential Learning Framework*. Retrieved December 7, 2020, from https://adue.engin.umich.edu/experiential-learning-framework/

Callewaert, J.H. (2019). Measuring the impact of experiential learning. In *ASEE Annual Conference and Exposition, Conference Proceedings*. https://doi.org/10.18260/1-2--33095

Callewaert, J., Millunchick, J., Woodcock, C., Jiang, K., & Edington, S. (2020). Developing a Framework for Experiential Learning. In *Amercian Society for Engineering Education Annual Conference and Exposition*. https://doi.org/10.18260/1-2--34414

Cantor, J. (1995). E*xperiential Learning in Higher Education: Linking Classroom and Community*. ASHE-ERIC Higher Education Report No. 7.

Carpenter, D.D., Harding, T.S., Sutkus, J.A., & Finelli, C.J. (2014). Assessing the ethical development of civil engineering undergraduates in support of the ASCE body of knowledge. *Journal of Professional Issues in Engineering Education and Practice*, *140*(4), 1–10. https://doi.org/10.1061/(ASCE)EI.1943-5541.0000177

Carter, D., Ro, H., Alcott, B., & Lattuca, L.R. (2016). Co-Curricular Connections: The Role of Undergraduate Research Experiences in Promoting Engineering Skills. *Research in Higher Education*, *57*(3), 363–393. https://doi.org/10.1007/s11162-015-9386-7

Chan, C.K.Y. (2012). Assessment for Community Service Types of Experiential Learning in the Engineering Discipline. *European Journal of Engineering Education*, *37*(1), 29–38. https://doi.org/http://dx.doi.org/10.1080/03043797.2011.644763

Charyton, C., Jagacinski, R.J., Merrill, J.A., Clifton, W., & DeDios, S. (2011). Assessing Creativity Specific to Engineering with the Revised Creative Engineering Design Assessment. *Journal of Engineering Education*, *100*(4), 778–799.

Charyton, C., & Merrill, J. A. (2009, April). Assessing General Creativity and Creative Engineering Design in First Year. *Journal of Engineering Education*, *98*, 145–156. https://doi.org/10.1002/j.2168-9830.2009.tb01013.x

CoE Strategic Planning Committee - Educational Experience Commission. (2018). Ann Arbor, MI. Retrieved from https://umich.app.box.com/s/32m2u2bz9zw9gqaa4ih4yfh3oxl3b28i

Colby, A., & Sullivan, W. (2008, July). Ethics Teaching in Undergraduate Engineering Education. *Journal of Engineering Education*.

Conger, A.J., Gilchrist, B., Holloway, J.P., Huang-Saad, A., Sick, V., & Zurbuchen, T.H. (2010). Experiential learning programs for the future of engineering education. *2010 IEEE Transforming Engineering Education: Creating Interdisciplinary Skills for Complex Global Environments*, pp. 7–13. https://doi.org/10.1109/TEE.2010.5508822

Consortium to Promote Reflection in Engineering Education. (n.d.). Retrieved June 2, 2020, from http://cpree.uw.edu/

Court, A.W. (1998). Improving Creativity in Engineering Design Education. *European Journal of Engineering Education*, *3797*. https://doi.org/10.1080/03043799808923493

Daly, S.R., Adams, R.S., & Bodner, A.M. (2012). What does it mean to design? A qualitative investigation of design professionals' experiences. *Journal of Engineering Education*, *101*(2), 187–219. https://doi.org/10.1002/j.2168-9830.2012.tb00048.x

Daly, S.R., Mosyjowski, E.A., & Seifert, C.M. (2014). Teaching Creativity in Engineering Courses. *Journal of Engineering Education*, *103*(3), 417–449. https://doi.org/10.1002/jee.20048

Davies, R., Zaugg, H., & Tateishi, I. (2015). Design and development of a cross-cultural disposition inventory. *European Journal of Engineering Education*, *3797*. https://doi.org/10.1080/03043797.2014.915289

Downey, G.L., Lucena, J.C., Moskal, B.M., Parkhurst, R., Bigley, T., Hays, C., … Nichols-Belo, A. (2006). The Globally Competent Engineer: Working Effectively with People Who Define Problems Differently. *Journal of Engineering Education*, *95*(2), 107–122. https://doi.org/10.1002/j.2168-9830.2006.tb00883.x

Duderstadt, J.J. (2008). *Engineering for a changing world a roadmap to the future of American engineering practice, research, and education*. https://doi.org/10.1007/978-1-4419-1393-7_3

Dukart, K. (2016). *Educating the New-Century Engineer: Understanding the Role of Extracurricular Project-Based Experiential Learning in Engineering Education*. University of Minnesota.

Dym, C., Agogino, A., Eris, O., Frey, D.D., & Leifer, L.J. (2005, January). Engineering Design Thinking, Teaching, and Learning. *Journal of Engineering Education*, pp. 103–120. https://doi.org/10.1109/EMR.2006.1679078

Finelli, C.J., Holsapple, M.A., Ra, E., Bielby, R.M., Burt, B.A., Carpenter, D.D., … Sutkus, J.A. (2012). An assessment of engineering students' curricular and co-curricular experiences and their ethical development. *Journal of Engineering Education*, *101*(3), 469–494. https://doi.org/10.1002/j.2168-9830.2012.tb00058.x

Fisher, D.R. (2013). *Educating Engineers for the 21 st Century: A Framework for Skill Development Through Co-Curricular and Extracurricular Involvement*. Massachusetts Institute of Technology.

Fisher, D.R., Bag, A., & Sarma, S. (2017). Developing professional skills in undergraduate engineering students through cocurricular involvement. *Journal of Student Affairs Research and Practice*, *54*(3), 286–302. https://doi.org/10.1080/19496591.2017.1289097

Fordyce, D. (1988). The Development of Systems Thinking in Engineering Education: An interdisciplinary model. *European Journal of Engineering Education*, *3797*. https://doi.org/10.1080/03043798808939427

Genco, N., Hölttä-Otto, K., & Seepersad, C.C. (2012). An experimental investigation of the innovation capabilities of undergraduate engineering students. *Journal of Engineering Education*, *101*(1), 60–81. https://doi.org/10.1002/j.2168-9830.2012.tb00041.x

Gilmartin, S.K., Thompson, M.E., Morton, E., Jin, Q., Chen, H.L., Colby, A., & Sheppard, S.D. (2019, January). Entrepreneurial intent of engineering and business undergraduate students. *Journal of Engineering Education*, pp. 1–21. https://doi.org/10.1002/jee.20283

Gosselin, D., Cooper, S., Lawton, S., Bonnstetter, R.J., & Bonnstetter, B.J. (2016). Lowering the walls and crossing boundaries: applications of experiential learning to teaching collaboration. *Journal of Environmental Studies and Sciences*, *6*(2), 324–335. https://doi.org/10.1007/s13412-015-0312-2

Graham, R. (2018). *The Global State of the art Engineering Education*. MIT School of Engineering.

Grant, M.J., & Booth, A. (2009). A typology of reviews: An analysis of 14 review types and associated methodologies. *Health Information and Libraries Journal*, *26*(2), 91–108. https://doi.org/10.1111/j.1471-1842.2009.00848.x

Green, H.E. (2014). Use of theoretical and conceptual frameworks in qualitative research. *Nurse Researcher*, *21*(6), 34–38.

Hallman, S.K., Wright, M.C., & Conger, A.J. (2016). *Development and Assessment of Student Creativity*. Retrieved from https://files.eric.ed.gov/fulltext/ED573966.pdf

Harrisberger, L., & others. (1976). *Experiential Learning in Engineering Education.* American Society for Engineering Education.

Herkert, J.R. (2000). Engineering ethics education in the USA : Content, pedagogy and curriculum. *European Journal of Engineering Education*, *3797*. https://doi.org/10.1080/03043790050200340

Hess, J.L., Strobel, J., Pan, R.C., & Morris, C.A.W. (2017). Insights from industry: a quantitative analysis of engineers' perceptions of empathy and care within their practice. *European Journal of Engineering Education*, *3797*. https://doi.org/10.1080/03043797.2016.1267717

Infusing Real World Experiences into Engineering Education. (2012). Washington D. C. https://doi.org/10.17226/18184

Itin, C.M. (1999). Reasserting the Philosophy of Experiential Education as a Vehicle for Change in the 21st Century. *Journal of Experiential Education*, *22*(2), 91–98. https://doi.org/10.1177/105382599902200206

Jaeger, B., Freeman, S., Whalen, R., & Payne, R. (2010). Successful Students: Smart or Tough? In *American Society for Engineering Education Annual Conference & Exposition* (pp. AC 2010-1033).

Johnson, B., & Main, J. (2020). The Influence of Experiential Learning on Student Professional Development: A Literature Review. In *Amercian Society for Engineering Education Annual Conference and Exposition*. https://doi.org/10.18260/1-2--35344

Keshwani, J., & Adams, K. (2017). Cross-Disciplinary Service-Learning to Enhance Engineering Identity and Improve Communication Skills. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, *12*(1), 41–61. https://doi.org/10.24908/ijsle.v12i1.6664

Knight, D.B., & Novoselich, B.J. (2017, February). What Turns an Engineer Into a Leader? *JEE Selects*.

Kolb, A.Y., & Kolb, D.A. (2009). Experiential learning theory: A dynamic, holistic approach to management learning, education and development. In *The SAGE Handbook of Management Learning, Education and Development*. https://doi.org/10.4135/9780857021038.n3

Kolb, D.A. (1984). *Experiential Learning: Experience as the source of learning and development*. Englewood Cliffs, NJ: Prentice Hall. https://doi.org/doi:10.1016/B978-0-7506-7223-8.50017-4

Kolb, D.A. (2015). *Experience as the Source of Learning and Development Second Edition*. Pearson Education, Inc. Upper Saddle River. https://doi.org/10.1002/job.4030080408

Kolb, D.A., Boyatzis, R.E., & Mainemelis, C. (2011). Experiential learning theory: Previous research and new directions. In *Perspectives on Thinking, Learning, and Cognitive Styles* (p.227). Mahwah, NJ. https://doi.org/10.4324/9781410605986-9

Kusano, S.M., Conger, A.J., & Wright, M.C. (2015). *Development and assessment of intercultural engagement.*

Kusano, S.M., Conger, A.J., & Wright, M.C. (2016). *Development and Assesment of collaboration, teamwork, and communication.*

Kusano, S.M., Wright, M.C., & Conger, A.J. (2016). *Development and assement of self agency and the ability to innovate and take risks.*

Lappalainen, P. (2009). Communication as part of the engineering skills set. *European Journal of Engineering Education*, *34*(2), 123–129. https://doi.org/10.1080/03043790902752038

Lerner, A.M.A. (2013). Gritty students: The effect of perseverance on retention for traditional and nontraditional students. In *American Society for Engineering Education Annual Conference & Exposition*.

Leydens, J., & Lucena, J. (2010). Listening as a Missing Dimension in Engineering Education: Implications for Sustainable Community Development Efforts. *Professional Communication, IEEE Transactions On*, *52*, 359–376. https://doi.org/10.1109/TPC.2009.2032383

Lohmann, J.R., Rollins, H.A., Hoey, J.J., Lohmann, J.R., Rollins, H.A., & Defining, J.J.H. (2006). Defining, developing and assessing global competence in engineers. *European Journal of Engineering Education*, *3797*. https://doi.org/10.1080/03043790500429906

Luckmann, C. (1996). Defining Experiential Education. *Journal of Experiential Education*, *19*(1), 6–7. https://doi.org/10.1177/105382599601900101

May, D., Wold, K., Moore, S., May, D., Wold, K., & Moore, S. (2015). Using interactive online role-playing simulations to develop global competency and to prepare engineering students for a globalised world. *European Journal of Engineering Education*, *3797*. https://doi.org/10.1080/03043797.2014.960511

Mcgee, J.E., Peterson, M., Mueller, S.L., & Sequeira, J.M. (2009). Entrepreneurial self-efficacy: Refining the measure. *Entrepreneurship: Theory and Practice*, *33*(4), 965–988. https://doi.org/10.1111/j.1540-6520.2009.00304.x

Meertens, R.M., & Lion, R. (2008). Measuring an individual's tendency to take risks: The risk propensity scale. *Journal of Applied Social Psychology*, *38*(6), 1506–1520. https://doi.org/10.1111/j.1559-1816.2008.00357.x

Morgan, J.K. (2018). Examination of the Development of Grit in First-Year Engineering Students. In *2018 FYEE Conference*.

Morris, T.H. (2019). Experiential learning–a systematic review and revision of Kolb's model. *Interactive Learning Environments*, *0*(0), 1–14. https://doi.org/10.1080/10494820.2019.1570279

National Academy of Engineering. (2005). *Educating the engineer of 2020: adapting engineering education to the new century* (Vol. 3). Washington D. C., D.C: The National Academies Press. https://doi.org/10.17226/11338

National Academy of Engineering. (2013). Educating Engineers: Preparing 21st Century Leaders in the Context of New Modes of Learning. In S. Olson (Ed.), *Educating Engineers: Preparing 21st Century Leaders in the Context of New Modes of Learning*. Washington D. C, D.C.: National Academy Press. https://doi.org/10.17226/18254

Oladiran, M.T., Uziak, J., Eisenberg, M., & Scheffer, C. (2011). Global engineering teams – a programme promoting teamwork in engineering design and manufacturing. *European Journal of Engineering Education*, *3797*. https://doi.org/10.1080/03043797.2011.573534

Passow, H.J., & Passow, C.H. (2017). What Competencies Should Undergraduate Engineering Programs Emphasize? A Systematic Review. *Journal of Engineering Education*, *106*(3), 475–526. https://doi.org/10.1002/jee.20171

Rasoal, C., Danielsson, H., & Jungert, T. (2012). Empathy among students in engineering programmes. *European Journal of Engineering Education*, *3797*. https://doi.org/10.1080/03043797.2012.708720

Reeve, D., Evans, G., Simpson, A., Sacks, R., Oliva-fisher, E., Rottmann, C., & Sheridan, P. (2015). Curricular and Co-Curricular Leadership Learning for Engineering Students. *Collected Essays on Teaching and Learning*, *8*.

Rico-garcía, M., & Burns, L.V.F. (2019). Intercultural communication in engineering studies: A key competence in global labour markets competence in global labour markets. *European Journal of Engineering Education*, *0*(0), 1–21. https://doi.org/10.1080/03043797.2019.1654980

Ro, H.K., & Loya, K.I. (2015). The effect of gender and race intersectionality on student learning outcomes in engineering. *Review of Higher Education*, *38*(3), 359–396. https://doi.org/10.1353/rhe.2015.0014

Seat, E., Parsons, R.J., & Poppen, W.A. (2001, January). Enabling Engineering Performance Skills: A Program to Teach Communication, Leadership, and Teamwork. *Journal of Engineering Education*, pp. 7–12.

Simmons, D.R., Creamer, E.G., & Yu, R. (2017). Involvement in Out of Class Activities: A Mixed Research Synthesis Comparing Outcomes of Engineering to Non- engineering Undergraduate Students. *Journal Fo STEM Education: Innovations Adn Research*, *18*(2), 10–16.

Simpson, A.E., Evans, G.J., & Reeve, D. (2012). A summer leadership development program for chemical engineering students. *Journal of Leadership Education*, *11*(1), 222–232. https://doi.org/10.24908/pceea.v0i0.3139

University of Michigan Students. (2019). *Experiential Learning Inititaive Proposal ELIProp*. Ann Arbor, MI.

Verdín, D., Godwin, A., Kirn, A., Benson, L., & Potvin, G. (2018). Understanding How Engineering Identity and Belongingness Predict Grit for First-Generation College Students. In *The Collaborative Network for Engineering and Computing Diversity Annual Conference*.

Walther, J., Miller, S.E., & Sochacka, N.W. (2017). A Model of Empathy in Engineering as a Core Skill, Practice Orientation, and Professional Way of Being. *Journal of Engineering Education*, *106*(1), 123–148. https://doi.org/10.1002/jee.20159

Walther, J., Miller, S.E., Sochacka, N.W., & Brewer, M.A. (2016, June). Fostering empathy in an undergraduate mechanical engineering course. In *ASEE Annual Conference and Exposition, Conference Proceedings*. https://doi.org/10.18260/p.26944

Wilkins, K.G., Bernstein, B.L., & Bekki, J.M. (2015). Measuring Communication Skills: The STEM Interpersonal Communication Skills Assessment Battery. *Journal of Engineering Education*, *104*(4), 433–453. https://doi.org/10.1002/jee.20100

Woodcock, C.S.E., Shekhar, P., & Huang-Saad, A. (2019). Examining Project Based Entrepreneurship and Engineering Design Course Professional Skills Outcomes *. *International Journal of Engineering Education*, *35*(2), 631–644.

Yi, S., & Duval-Couetil, N. (2018). What Drives Engineering Students To Be Entrepreneurs? Evidence of Validity for an Entrepreneurial Motivation Scale. *Journal of Engineering Education*, *107*(2). https://doi.org/10.1002/jee.20199

Zhang, M., Kranov, A.A., Beyerlein, S.W., McCormack, J.P., Pedrow, P.D., & Schmeckpeper, E. (2015). Investigating a scenario-based performance assessment of engineering professional skills. In *5th IEEE Integrated STEM Education Conference* (pp. 230–235). IEEE. https://doi.org/10.1109/ISECon.2015.7119930

Zheng, W., Shih, H.R., & Mo, Y.L. (2009). Integration of cognitive instructions and problem/project-based learning into civil engineering curriculum to cultivate creativity and self-directed learning skills. In *American Society of Engineering Education Annual Conference*.

Zoltowski, C.B., Buzzanell, P.M., & Oakes, W.C. (2013). Utilizing an engineering ethical reasoning instrument in the curriculum. In *American Society for Engineering Education Annual Conference & Exposition*.

APPENDIX

APPENDIX 1
COMPETENCY RUBRICS

		Exploring (1)	Engaging (2)	Explaining (3)
Communication	Listening	The student is able to demonstrate an understanding of and respond to basic requests appropriately.	The student practices active listening and notices nonverbal cues but doesn't always know how to respond appropriately.	The student practices active listening, notices nonverbal cues, and is able to confidently receive and understand constructive feedback.

	Writing	The student writes a report but only incorporates 1-2 of the following well: context and purpose for writing, content development, sources and evidence, genre and disciplinary conventions, and control of syntax and writing mechanics.	When writing, the student incorporates 3-4 of the following well: context and purpose for writing, content development, sources and evidence, genre and disciplinary conventions, and control of syntax and writing mechanics.	When writing, the student is intentional to incorporate all of the following: context and purpose for writing, content development, sources and evidence, genre and disciplinary conventions, and control of syntax and writing mechanics.
	Speaking – Small Group or Informal Settings	The student is able to "translate" content, expectations, etc. and communicate only with individuals that share their background (education, demographic, other experience).	The student is able to "translate" content, expectations, etc. and communicate with individuals across backgrounds depending on the complexity of content being discussed.	The student is able to "translate" content, expectations, etc. and communicate with individuals across backgrounds by accounting for and adjusting to differences.
	Presenting – Oral and Visual	The student develops a presentation but only incorporates 1-2 of the following: consideration of best practices for organization of the presentation, use of language appropriate for the audience, delivery techniques to improve engagement, supporting material, and a strong central message.	When developing a presentation, the student may incorporate 3-4 of the following: best practices for organization of the presentation, use of language appropriate for the audience, delivery techniques to improve engagement, supporting material, and a strong central message.	When developing a presentation, the student is intentional to incorporate all of the following: considering best practices for organization of the presentation, use of language appropriate for the audience, delivery techniques to improve engagement, supporting material, and a strong central message.
Creativity	Production of Novel Ideas	The student values creating a novel or unique idea or product in the ideation process but may struggle to produce novel ideas.	The student creates one or more novel or unique ideas or products in the ideation process but doesn't apply them to the problem solution.	The student extends a novel or unique idea or product from the ideation process to create new knowledge or knowledge that crosses boundaries.
	Production of Useful Ideas	The student values creating a useful idea or product in the ideation process but may struggle to produce ideas.	The student creates one or more useful ideas or products in the ideation process but doesn't apply them to the problem solution.	The student extends a useful idea or product from the ideation process to create new knowledge or knowledge that crosses boundaries.

	Applying Divergent and Convergent Thinking	The student is newly aware of divergent and convergent thinking processes, but this may be their first exposure.	The student uses some divergent and convergent thinking strategies but to a limited extent.	The student uses divergent and convergent thinking strategies throughout the design or problem-solving process.
	Innovation	The student recognizes existing connections among novel and/or useful ideas or solutions.	The student synthesizes novel and/or useful ideas or solutions into a coherent whole.	The student transforms novel and/or useful ideas or solutions into entirely new forms to solve a problem.
Empathy	Cognitive Empathy	The student is not initially aware of the diverse perspectives in a team setting but, once made aware, attempts to understand those perspectives.	The student approaches a team setting knowing that there are diverse perspectives and experiences and aims to understand them.	The student implements strategies for understanding others' perspectives early in a team setting (e.g. a team norming stage) as well as during conflict in team settings.
	Emotional Empathy	The student is not initially able to understand the emotions of another or approach a problem from their perspective but attempts to.	The student is able to understand the emotions of another but may struggle to approach a problem from their perspective.	The student is able to understand the emotions of another and approach a problem from their perspective.
	Empathetic Response	The student is not initially aware of strategies to respond to conflict or differing perspectives through empathetic cognitive or emotional means.	The student does respond to conflict or differing perspectives through empathetic cognitive or emotional means but to a limited degree or in limited scenarios.	The student consistently responds to conflict or differing perspectives through empathetic cognitive or emotional means.
Entrepreneurship	Entrepreneurial Skills	The student is inexperienced in performing the tasks (i.e. Searching, Marshaling, Planning, Implementing People, and Finance) associated with entrepreneurship, in any setting.	The student is familiar with performing some tasks (i.e. Searching, Marshaling, Planning, Implementing People, and Finance) associated with entrepreneurship, mostly in a design setting.	The student is comfortable with performing tasks (i.e. Searching, Marshaling, Planning, Implementing People, and Finance) associated with entrepreneurship, in multiple settings.
	Entrepreneurial Intent	The student has not yet been exposed to business-like or start-up-related projects	The student is willing to perform business-like or start-up-related projects and job responsibilities.	The student actively seeks out projects and job responsibilities in line with work

		and job responsibilities.		performed in business or start-up settings.
	Intrapreneurship	The student is risk-averse in a business or project setting.	The student is willing to take risks in a business or project setting but rarely suggests the action themselves.	The student suggests potentially risky actions in a business or project setting when they believe it will push the project forward.
Ethics	Knowledge of Ethics	The student has recently become aware of engineering-specific codes of ethics.	The student is aware of and is able to reference appropriate engineering codes of ethics resources.	The student is familiar with most of the engineering codes of ethics and has incorporated that knowledge in decision-making processes.
	Ethical Reasoning	The student does not yet consciously consider ethical implications in decision making.	The student occasionally considers ethical implications in decision making but struggles to justify decisions using ethical reasoning.	The student regularly considers ethical implications in decision making and is able to justify decisions using ethical reasoning.
	Ethical Behavior	The student does not yet consistently consider the ethics of their decisions or behavior.	The student does not always engage in behaviors consistent with their ethical reasoning (positive or negative).	The student is able to engage in behaviors consistent with their ethical reasoning (positive or negative).
Global and Cultural Awareness	Cultural Competence or Awareness	The student is considering what they know about cultures, social values, political systems, beliefs, or ways of life of a specific population when proposing an engineering solution for the first time.	The student considers what they know about cultures, social values, political systems, beliefs, or ways of life of a specific population in their engineering solutions but may not consider how to appropriately interact with people who are different than themselves.	The student is able to consider cultures, social values, political systems, beliefs, or ways of life of a specific population in their engineering solutions and appropriately interact with people who are different than themselves.
	Global Competence or Awareness	The student is considering international geopolitical or cultural issues when solving global problems or proposing engineering	The student considers big picture international geopolitical or cultural issues but not the lived experience of the individuals' impacted by their engineering solutions.	The student is able to consider international geopolitical or cultural issues and the impact of peoples' differing lived experiences in their engineering solutions.

		solutions for the first time.		
	Diverse Workplace Competence or Awareness	The student has not yet considered or is considering for the first time the need to understand differing lived experiences in the workplace.	The student occasionally considers differing lived experiences in the workplace when resolving or avoiding conflict.	The student is able to consider and address differing lived experiences in the workplace to foster an inclusive, productive work environment.
Grit / Persistence / Resilience	Perseverance for Long-Term Goals	The student has set long-term goals but has not shown persistence toward those goals.	The student has set long-term goals and has made steps towards persisting through many of them. They may occasionally give up a goal.	The student has set long-term goals and has made consistent effort toward persisting or achieving those goals.
	Overcoming Setbacks	The student struggles to start again after encountering a setback.	The student may start again after encountering a setback but with less enthusiasm or determination.	The student consistently starts again after encountering a setback with equal enthusiasm or determination.
	Pivoting when Appropriate	The student has not yet had to consider the need to pivot when encountering difficulty in achieving goals.	The student may pivot when encountering difficulty in achieving goals but frequently at inappropriate times (i.e. they wait too long or give up too quickly).	The student consistently assesses their own performance and appropriately pivots when encountering difficulty in achieving goals necessitates.
	Navigating a Hostile Workplace	The student is unfamiliar with strategies to navigate hostile work environments but gains exposure through formal (classroom lesson) or informal (real-world experience) means.	The student has limited experience navigating hostile work environments and is developing strategies to address those environments.	The student is familiar with strategies for navigating hostile work environments and is confident in their ability to do so.
Leadership	Team Leadership	The student often defers to the opinions of others on a team and, when tasked with leading, employs few strategies to facilitate group work.	The student demonstrates an awareness of team dynamics and employs strategies to facilitate group work on occasion.	The student demonstrates an awareness of team dynamics, frequently employs strategies to facilitate group work, and demonstrates an ability to resolve conflict on the team.

	Organizational Leadership	The student is aware of the goals of an organization and works to contribute to the achievement of those goals.	The student is able to explain the goals of an organization and works with others to contribute to the achievement of those goals.	The student demonstrates an ability to align goals, communicate expectations when they aren't being met, and facilitate the work of a group towards the goals of an organization.
	Societal Leadership	The student gains exposure to considering the societal impact of their engineering work when making decisions as a leader.	The student demonstrates some understanding of the societal impact of their engineering work when making decisions as a leader.	The student understands and places emphasis on the societal impact of their engineering work when making decisions as a leader.
Lifelong Learning	Self-Agency in Educational Choices	The student makes educational choices based on role models, instructor, or advisor recommendations.	The student considers educational choices based on role models, instructor, or advisor recommendations as well as their own experiences.	The student seeks out advice and resources from role models, instructor, or advisor recommendations but also uses their own experiences to make educational choices.
	Ability to Seek Out Appropriate Sources to Learn on One's Own	The student depends on the resources provided in a learning environment and may not have experience seeking out additional resources.	The student uses the resources provided in a learning environment and are able to seek out additional resources when prompted.	The student uses the resources provided in a learning environment and are able to seek out appropriate additional resources to improve their understanding of a topic.
	Knowing When to Ask for Help	The student gives up quickly and seeks help after encountering a problem they do not understand, OR they struggle with the problem at hand for an extended time without asking for help.	The student becomes more comfortable asking for help after attempting to solve the problem on their own for a short while.	The student consistently works on the task at hand before asking for help. When they cannot solve the problem on their own, they strategically ask for help.
Ability to Accept and Manage Risk	Being Proactive about Risk Associated with Engineering Work	The student is not initially aware of the need to consider the risks associated with their proposed engineering solution.	The student considers some of the risks associated with their proposed engineering solution but not all of them.	The student is able to thoroughly consider possible risks and take appropriate precautions to address the most important risks in an engineering solution.

	Recognizing the Need to Take Risk	The student avoids risks in all areas of a project.	The student is willing to take risks only if viewed as unavoidable.	The student actively seeks out and follows through on untested and potentially risky directions or approaches to the assignment in the final product.
	Consideration of Risk v. Reward in Decision Making	The student does not initially consider potential benefits (rewards) of a decision when considering possible risk.	The student considers potential benefits (rewards) of a decision when considering possible risk but not all of them.	The student is able to thoroughly compare risks and rewards associated with a given decision and take appropriate action in an engineering solution.
Systems Thinking	Consideration of the Multi-Level Goals of the Project	The student considers solutions in a manner that addresses the problem statement but has not yet needed to consider the multiple levels of project goals.	The student considers solutions in a manner that addresses the problem statement and acknowledges the need to recognize multiple levels of project goals.	The student considers solutions to a problem in a manner that thoroughly and deeply addresses multiple contextual factors, at multiple levels of project goals.
	Ability to Break Down a System into Discrete Pieces and Put it Back Together in a Coherent Solution	The student struggles to see the problem as parts of a whole.	The student recognizes discrete pieces of a problem and can draw from multiple examples, facts, or theories to understand the pieces but struggles to combine the pieces to create a solution.	The student is able to draw from and combine multiple examples, facts, or theories from more than one field of study or perspective to understand discrete pieces of a problem and combine them to solve complex problems in original ways.
	Ability to Make Appropriate Estimates when Problem-Solving	The student is experiencing how to appropriately connect engineering and/or scientific principles in order to make estimates during problem solving for the first time.	The student makes connections between engineering and/or scientific principles and the problems they wish to solve but occasionally make an inappropriate assumption or estimation.	The student appropriately uses basic engineering and/or scientific principles to formulate estimates or create models describing the behavior and performance of parts of a system or problem.
Teamwork	Valuing the Development of Shared Rules, Norms, Structure	The student makes an effort to understand the norms of the team and follow shared rules but has limited contribution to the development of them.	The student actively engages with the development of shared rules, norms, and team structures and personally follows them.	The student actively engages with the development of shared rules, norms, and team structures and monitors team dynamics with

			regarding the adherence to them.
Recognition of and Commitment to a Common Purpose / Goal	The student completes their team assigned tasks on time but otherwise is not invested in project completion.	The student completes their team assigned tasks on time and checks with teammates about project goals and progress occasionally.	The student completes their team assigned tasks on time, checks with teammates about project goals and progress, and offers help when necessary.
Ability to work across Disciplinary Differences	The student recognizes that working across disciplines is common in engineering practice but cannot articulate the value.	The student recognizes connections between specific project tasks and a given discipline and works to contribute equally.	The student expresses the value of multiple disciplines in solving an engineering problem, and demonstrates an ability to communicate effectively on multidisciplinary teams.

APPENDIX 2
ABET CRITERIA FOR ENGINEERING PROGRAM STUDENT OUTCOMES (2019-2020)

Criterion 3. Student Outcomes

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. an ability to communicate effectively with a range of audiences
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies