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Assessing and Communicating Professional Competency Development Through Experiential Learning

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Assessing and Communicating Professional Competency Development through Experiential Learning

This is a work-in-progress paper submitted to the ASEE Cooperative & Experiential Education Division.

Abstract

A new experiential learning initiative at a large R1 institution seeks to provide students with a framework to 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 (communication, creativity, empathy, entrepreneurial mindset, ethics, global/cultural awareness, grit/persistence/resilience, leadership, lifelong learning, risk management, systems thinking, and teamwork). Although most students at this institution participate in experiential learning, the framework aims to provide students with richer, more meaningful experiences through intentional engagement and reflection. Through several informal conversations, both students and employers have expressed the need for students to reflect and be able to better communicate the value of their experiences in relation to their technical skills and career aspirations. This point is reinforced by recent industry reports which emphasize the difficult time employers have in finding employees with the professional skills needed for the workplace.

An objective of the experiential learning framework is to support reflection and competency development at scale, but the best model for this has yet to be identified. Indeed, it may be that multiple pathways (existing courses, new courses, online modules, etc.) will need to be available to students. Therefore, we piloted two new approaches for students to reflect and communicate their own competency development. The first is the creation of a new 400-level professional course that aims to develop students' understanding and communication of competency development via structured reflection. The second is a pre/post assessment of a faculty-identified set of competencies in an existing project-based, discipline-specific technical course.

The new course takes a retrospective approach and asks students to leverage their experiences to create a set of stories that in turn highlight their values and guiding principles. Their final assignment was to develop a professional document, such as a personal statement, LinkedIn page, or resume, grounded in one or more competencies and informed by feedback from peers and alumni mentors. The pre/post assessment effort is a partnership with a faculty member leading a course on systems engineering and business leadership processes. The faculty member selected a subset of the key competencies (leadership, risk management, systems thinking, and teamwork) which aligned with course objectives. The pre/post assessment provides an opportunity for students to self-assess and reflect on their competency development over the course of the semester by focusing on their specific project.

This paper will start with an overview of the experiential learning initiative and a description of the key competencies being used to guide reflection and communication efforts. Next, detailed descriptions will be provided for both the new course and the pre/post assessment effort including deidentified samples of student work. This will be followed by an initial assessment of student outcomes, a review of student feedback, and plans for modifying these efforts in the

future. Finally, a description will be provided for how these efforts are also helping to inform the creation of a new online tool that will provide additional support for delivering content at scale to students around competency development, reflection, and communication.

Introduction

Experiential learning opportunities have been described as important in higher-education contexts for many years [1] as these opportunities have been linked to better career placement and recruitment and retention efforts [2]. Experiential learning opportunities have also been identified as a key pedagogical feature of engineering education as noted in the recent MIT report *The Global State of the Art in Engineering Education* [3] and others [4-8]. This emphasis may stem from experiential education's alignment with engineering-design education efforts [9], its potential to support the development of professional competencies [10, 11], or its ability to produce more innovative, career-ready engineers [12, 13].

In response to the important role of experiential learning in engineering education, a new experiential learning initiative in a college of engineering at a large R1 institution seeks to provide students with a framework to 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 Table 1 below and Appendix A for a full list of competencies and their definitions). Through a rich opportunity mix including hundreds of student organizations, curricular opportunities, co-curricular opportunities, research and entrepreneurial experiences, team competitions, and others, 97% of 2019 engineering graduating seniors reported involvement with a least one type of the following experiences—research, civic engagement, creative work, international experience, entrepreneurship, client projects, or internships. However, we have found that the intentionality of development and measurement of professional competencies was limited in these efforts [13-15]. Similar issues regarding measuring the impact of experiential learning efforts in engineering education more broadly have been documented [16, 17]. This point is reinforced by recent industry reports, which emphasize the difficult time employers have in finding employees with the professional skills needed for the workplace [18, 19].

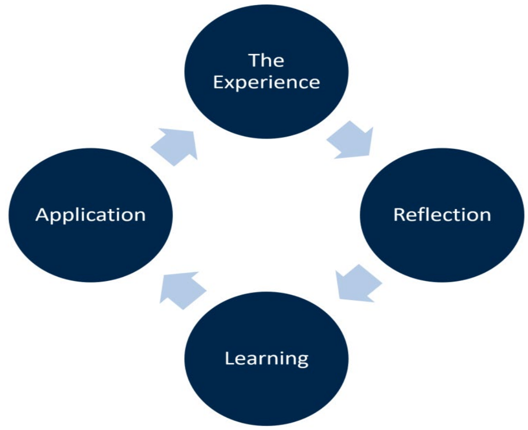
Table 1: Key Professional Competencies [13, 15]

• Communication • Creativity • Empathy • Entrepreneurial Mindset	• Ethics • Global/Cultural Awareness • Grit/Persistence/Resilience • Leadership	• Lifelong Learning • Risk Management • Systems Thinking • Teamwork

The Experiential Learning Framework

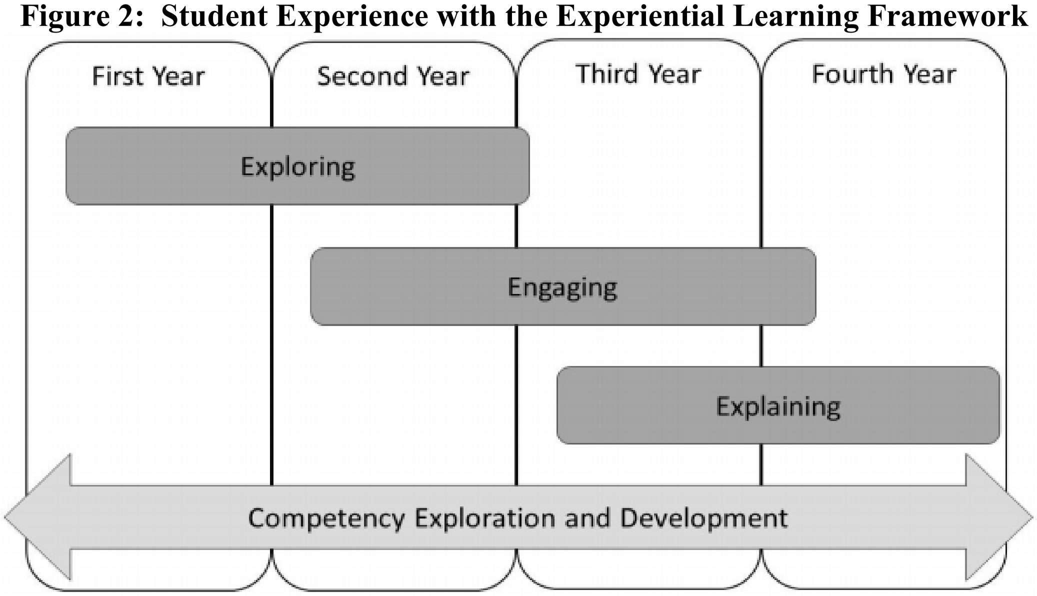
The Experiential Learning Framework (ELF) is an approach in the college of engineering at our institution to support student engagement in experiential learning as well as assessment of student development. Frameworks in education literature are often used as a structured strategy for developing a study or interpreting data collected within a study [20]. 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 pathway for how students engage or how it should be assessed. We aligned the goals of ELF with conceptualizations of the experiential learning process as defined by Kolb and others [21-24]—the iterative process involving conceptualization (learning), active experimentation (application), concrete experience (the experience), and reflective observation (reflection), see Figure 1 below.

Figure 1: Kolb's Model of Experiential Learning



An objective of ELF is to support reflection and competency development at scale. While we have developed a set of rubrics (learning outcomes, reflection prompts, and assessment indicators, see Appendix B1 and B2 for an example) [13], the best model for competency developed has yet to be identified. Indeed, it may be that multiple pathways (e.g., existing courses, new courses, online modules) will need to be available to deliver ELF to students, see Figure 2 below. Therefore, we are piloting two new approaches for students to reflect and communicate (or explain) their own competency development. The first is the creation of a new 400-level professional course that aims to develop students' understanding and communication of competency development via structured reflection. The second is a pre/post assessment of a faculty-identified set of competencies in an existing project-based, discipline-specific technical course.

Figure 2: Student Experience with the Experiential Learning Framework



Piloting New Approaches

During fall 2020, two new approaches—ENGR 490 and AERO 495—were used to engage students in ELF. ENGR 490 was a new professional course to engage students in iterative reflection about the competencies, and AERO 495 was an existing course that was modified to engage students with an instructor-chosen subset of the competencies. In the following two sections, each approach, its collected data, and its preliminary findings are discussed.

ENGR 490

ENGR 490 is a half-semester 1-credit course, first offered during fall 2020, designed to support upper-level students through reflection of their past experiences and creation and application of skills that will guide their professional futures. In the course, students iteratively reflect on and communicate their past experiences and development of competencies through writing stories; drafting values and guiding principles; connecting with mentors; and applying learning to early-career decision-making. At the end of the course, students were able to:

1. Describe their growth in and mastery of competencies in the context of their undergraduate experiences.
2. Define social capital and increase their social capital by identifying one peer and one professional to ask salient questions to, receive meaningful answers from, and make challenging decisions about students' personal and professional futures.
3. Design a set of guiding principles and values for their personal and professional futures, and use their guiding principles and values to:
    a. Describe what being an engineer means for them and their responsibility in serving the common good.
    b. Support personal and professional decisions using their guiding principles and values.
    c. Inform the creation of professional documents (e.g., resumes, personal statements).

Students began the course by briefly describing formative experiences during their undergraduate years (e.g., courses, student organizations, internships) and identifying mentors (e.g., faculty, alumni, industry members), with whom they could connect. Guided by prompts, students then wrote short stories around specific, salient moments in those formative experiences. Through iterative exercises within small groups and with mentors, students reflected on their stories and identified themes, which they used to create a set of values and guiding principles. Students then applied those values and guiding principles to create professional documents (e.g., resumes, personal statements, LinkedIn biographies) or support their early-career decisions (e.g., selecting a job offer).

Following the completion of the course, students who completed ENGR 490 during fall 2020 were invited via email to participate in either a focus group or individual interview. Students were contacted only after grades for the course had been finalized. During each session, students were asked questions about their experience in the course (see Appendix C) in order to assess their learning and identify ways to improve the course. In total, 6 of the 11 students enrolled in the course participated. Recordings of focus groups and interviews were transcribed, and transcripts were analyzed using thematic coding and analysis to identify specific learning outcomes and course improvement recommendations as well as to inform the broader objectives of ELF.

Findings

Several learning outcome themes were identified through the analysis: 1) understanding the purpose of the course, 2) the value of reflection, 3) the value of input from others, 4) learning from failure.

Understanding the Purpose of the Course

As this was the first time the course was offered, there were a few different understandings about what the course was about. Some students thought the course might prepare them with financial management skills for after college, how to communicate in the workplace, or how to be successful in graduate school. As one mechanical engineering student noted:

> *I don't remember this correctly, but when I signed up for the course, I think, the idea was that this would be a little bit more of like the skills for when you actually leave college. So, for example, ... like taxes or, you know … how would you communicate with people who are higher status compared to you. ...how to be an effective engineer in the workspace, or even like in grad school. Like how do you communicate with your professors... How do you communicate with your boss.*

While not entirely aligned with the course objectives, the student did understand that a key aspect of the course involved building communication skills (one of our competencies). While we did not offer financial management tips, we worked with students on how to communicate their experiences and demonstrate their competencies and principles to potential employers. This comment helped us understand the need to be clearer about course objectives and expectations.

The Value of Reflection

As we were using Kolb's model to guide our work, emphasizing reflection was key to our plans for ENGR 490. We had planned the course for upper level students with the expectation that they would have several experiences from which to draw upon. We did not stipulate specific experience but noted in the course description that to succeed in the course, students must have had at least one experiential (i.e., active, concrete, contextual) experience. These experiences could include those in student organizations and design teams, during study abroad, with undergraduate research, at conferences, or others. As noted in the course description above we relied heavily on writing and story development as a way for students to reflect. Another mechanical engineering student noted:

> *I've told other people before, but I feel like this class let me take it a step further at the end, reflecting back about why it's important, how it relates to my personal development as an engineer. Even in the immediate… short term, I found myself telling some interviewers, some of these same stories, realizing that... it's useful... immediately like a week after we do it in class. In addition to the long term future.*

Similarly, an electrical engineering student also noted:

> *I think also kind of helped as well because you were kind of like, oh, you did things without even kind of realizing that you were doing them, you had these competencies that you're like, oh, like this is kind of like what fits into and I think that was nice to reflect and... see... what do you change how you changed throughout...*

These quotes demonstrate that students were able to develop insights from their experience that not only helped them understand their abilities as engineers, they could also use that in their exchanges with interviewers and potential employers.

Value of Input from Others

A third theme concerned the value of input student's received from others. This included peer input during class and from mentors. Peer input was primarily derived from peers in a student's pod (small group of 3-4 students). For most of the course, students met regularly with the same pod members in order to develop a sense of familiarity and trust with sharing their stories and reflections. As part of the course, students were also matched with mentors. In general, these for alums of the college who have volunteered to be matched with students seeking to talk about post-graduate plans. A mechanical engineering senior noted:

> *...I think it's also not only just us personally having the opportunity to reflect, but the second step of having other people reflect on our experiences and getting that outside perspective that we wouldn't probably normally get. ...And I think that's definitely something that I wouldn't have made the connection of without this class. So I guess it's like seeing my stories from an outsider's perspective.*

A computer science student offered the following about their mentor:

> *So actually, one of the main things that... helped me really understand what my values really are is when I connected with my industry mentor. So when I met with him, I was like really awkward and I didn't really feel that comfortable asking him questions, but at a certain point, I was able to talk to him and asked him if he had any sort of like values or sort of vision of what he wanted to like have out of his career and out of his life in general. And he was able to really easily tell me values and things that he used to help guide his decision making process and you know, when he would leave a company, for example... It was because of... the certain reasons that conflicted with his values and conflicted with his goals. And because of that it helped make it a lot more real to me rather than just... reading off these competencies.*

This and other input from students in the course affirmed our plans to emphasize input from others as part of the reflection process. This will need to be a key component of any plans to deliver content at scale.

Learning from Failure

A fourth theme that emerged from the student input was the importance of recognizing and learning from failure. This notion is incorporated into the competencies but it also runs counter to the norms of success and accomplishment. When asked about how the course supported reflective learning, a mechanical engineering student noted:

Like I mentioned, there are just some things that I think would be really beneficial... For example, just emphasizing the fact that it's okay to have messed up as a XXXX engineer, like when you were in college, sometimes it's difficult to admit or saying like I struggled and I think that if there was an emphasis on it, I think there would be like maybe a greater bit of acceptance or just greater bit of vulnerability. It's, it's tough because people, communication and being able to admit stuff like that is very tough, but I think I would like an emphasis on that because it's important. It's, it's how you actually are able to reflect and be like, well, I could have done things like this or I did this because XYZ …

This input prompted us to add content to the course during the second interaction (winter 2020) on sharing constructive feedback to help establish norms for when students share their stories. A final quotation sums up what we hoped to accomplish with this course and inspires us to create the structures that can support all our students.

I feel like this class really helped in almost establishing a roadmap for myself because at the end of my four years since I'm the first in my family to go to college and finish college too, I didn't know if I did college correctly. Like the places that I applied to, the recruiters I tried to talk with them and it seemed like things weren't going well and I really doubted if I did university correctly. Like if I have done, if I've done anything. Sometimes it's almost like a panic of like, well, what have I done in the four years that I was here. And so this class, as we touched on it… I was able to reflect on even the small things like classwork or class projects and even just like study abroad and be able to say like here, here are my experiences. These are like the competencies that I've learned through those experiences, even if it's so small... I still remember like XXXX's story where he was... able to extract like the competencies, just from that little story. And like put that into perspective, like, wow, well I can do the same. I can do the same with my little stories that I've done here at XXXX and so this course really helped establish that roadmap and say like you have done a lot of things in these four years. And you're able to, like, now that you have this roadmap, you're able to almost effectively communicate what you have done, your competencies, and what you're looking forward to in the future.

Takeaways

In addition to the themes identified above, students shared several other recommendations for improving the course. This included challenges as a result of COVID-19, more work with the competencies, and strategies to help students prepare for in-class activities.

ENGR 490 faced numerous challenges due to COVID-19. Our effort to create an inclusive student experience led us to offer the course on three platforms: in-person, synchronous online, and asynchronous online. This essentially divided the students into two groups—synchronous and asynchronous. Students expressed both appreciation for an in-person experience but also the challenges of engaging with their peers across multiple platforms. For winter 2021, we are only offering the course in an online synchronous format. While it's helpful to have everyone on the same platform, we are looking forward to a return to an in-person environment in fall 2021.

Another takeaway from student input and our own reflection on the course has been to include more direct engagement with the competencies. For winter 2021, we have integrated more direct work with the competency rubrics such as working directly with the reflection prompts.

A third takeaway were ideas to help students better prepare for and participate in activities during class. Several students suggested receiving more directed writing prompts in advance, beginning the course by listing ideas (e.g., formative experiences, mentor feedback) to draw from during class activities for the semester, and sharing examples of student work from previous semesters to help them better understand their assignments. We have created more structured writing prompts to guide student writing and collected several examples of student work, with students' permission, to demonstrate ways to approach assignments.

AERO 495

To collect data and improve reflection activities related to the development of the experiential learning framework, we also partnered with an experiential, upper-level aerospace course. AERO 495 is an upper-level pilot version of a course that engages students on design teams in curriculum aimed at improving systems thinking and leadership skills. The course was developed and taught by an aerospace engineering professor of practice with 31 years of experience in industry. The course curriculum aims to create an environment similar to what students would experience in industry and covers topics such as systems engineering, project management, effective teams, risk management, verification and validation, manufacturing, and performance management. At the end of the course, students were expected to have skills to:

- Confirm a product or technical project meets customer needs and/or requirements using disciplined tools and processes.
- Establish a detailed project plan, with dependencies, key milestones and go/no-go decision points, and backup plans.
- Conduct formal and effective gateway and design reviews, with objectives, success criteria, and standard communication proformas.
- Create and deliver effective technical and business presentations, knowing the audience and tailoring the messages appropriately.
- Decide which manufacturing process(es) to use for specified applications, understanding the benefits and limitations (including cost, timing, quality).
- Use industry standard tools (e.g. FMEA, V&V) to establish potential failure modes, and eliminate/mitigate risk through clever design and validation practices.
- Establish and sustain effective teams, including valuing diversity in the very general sense (gender, ethnicity, operating styles, communication styles, diverse viewpoints).

Participants in the course were part of three aerospace-focused design teams on campus (two drone teams, one electric airplane team) ranging from their second to their fifth undergraduate year.

We worked collaboratively with the AERO 495 course instructor to identify competencies that align with topics covered in their course and create a survey instrument to explore student development. Four competencies—leadership, teamwork, systems thinking, and risk management—were identified. We selected two open-ended reflective prompts developed by our research team using resources from a review of literature on the competencies [13] and a set of pre-established quantitative survey items [5, 25] to include in a pre- and post-course survey format (see Appendix D). At the beginning of the semester, a brief (~10 minute) lecture about the framework and selected competencies was given in the course. Students were then directed to the online survey and given hard copies of a consent form to indicate their preference for how their data was used (as completion credit only, de-identified and given to the instructor for course improvement, and/or for the research purposes of our team). All data collected was then coded and shared with the appropriate parties according to plans approved by our University's IRB (HUMXXXX). Students were also asked for feedback on the clarity of the questions and structure of the survey which were included in order to improve future data collection efforts.

Findings

Fifteen students gave permission to use their pre-course responses and sixteen gave permission to use their post-course responses. Survey responses were analyzed quantitatively. Descriptive statistics are provided in Table 2. Rubrics to assess and assign a score to qualitative responses have been developed for future use in assessment efforts within the experiential learning framework (see Appendix B2 for rubric example). An example of how students' responses were scored for one of the leadership reflection prompts (e.g., Keeping in mind the definition of leadership provided, can you give an example of a situation where an engineer might use their leadership skills in a team setting? How would you identify an engineer-leader in a team setting?) can be found below:

Exploring-Level Response (Score 1): *I think being a leader is very related to the previous question about working on a diverse team.* ***It's a leader's job to make sure the team works well together, trusts each other, and each member is contributing.***

Explaining-Level Response (Score 3): *It is important to have leadership skills when working with others because a team requires organization, and everyone must contribute something to the end product.* ***All members must have leadership qualities when communicating with other team members.*** *For example, if one team member has an idea, it is their responsibility to speak up and mention that idea to the others****. It is also important to decide the different roles each member will play, taking each person's skill sets in mind.*** *Those are important qualities of a leader.*

Students reported marginal increases in teamwork and systems thinking competencies and no increase or a decrease in leadership and risk management competencies according to the quantitative scales. As measured by our rubrics, responses to the open-ended questions indicated a marginal increase in leadership, risk management, and systems thinking competencies with a small decrease in teamwork competencies. As a pilot, we are currently still exploring what the changes in development and differences across quantitative and qualitative measures might mean. In this course sequence in particular, students have the opportunity to learn about the competencies measured in the first semester and apply them in the second. We expect a more noticeable change from the beginning of the academic year to the end, which is data that is still being collected. Additionally, a small sample size and scale ((1-5) and (1-3)) contribute to the small changes observed. Engaging a higher number of participants in future work on developing these assessment strategies may be beneficial for seeing statistically testable patterns in development of the competencies.

Table 2. Average Scores for Quantitative and Qualitative Competency Responses of AERO 495 Student Pre- and Post-Course

	Competency	Pre-Course Response (n = 15)	Post-Course Response (n = 16)
Quantitative Likert-Like Scale Scores (1-5)	Leadership	3.9	3.9
	Teamwork	4	4.2
	Risk Management	3.2	2.9
	Systems Thinking	3.7	4.1
Quantified Qualitative Responses to Open-Ended Questions (1-3)	Leadership	1.7	1.9
	Teamwork	2.3	2.2
	Risk Management	2.2	2.5
	Systems Thinking	2.4	2.7

We also asked students to provide feedback for how to improve reflective prompts and the format of questions. Students expressed generally positive perceptions of the survey and reflective questions. Students appreciated being provided the definition of the competency they were reflecting on and described the activity as valuable:

"I really enjoyed these questions, and honestly really enjoyed thinking about these questions as a strategic approach to project management this year and understanding what my own goals are for my team."

The most informative constructive feedback received was related to the definition of systems thinking. Students perceived the definition as confusing and containing a lot of parts and struggled to see how the questions related to the definition. The pilot version of AERO 495 is a two-semester course sequence. As such, we have plans to collect data using the same online survey format at the end of the second semester. We plan to examine patterns for how students responded to the reflective prompts across the three timepoints to inform the use of reflective prompts in similar future course collaborations and ELF more broadly. We will also look for patterns in quantitative item responses to help inform how pre-established quantitative measures could be used in conjunction with other aspects of competency assessment within ELF.

Informing Other ELF Objectives

Finally, a key piece of our work to date is developing framework resources at scale—particularly the creation of an online platform to support competency-based learning. Building from the primary ELF objectives, the platform will support all undergraduate students with exploring and engaging in meaningful experiences, as well as reflecting on and communicating the value of the core competencies they have developed. The platform will also track their progress in the competencies so that students can understand their strengths and areas for improvement and so that they can recognize their growth over time.

We plan to launch the online platform this fall through a first-year course which reaches more than half of our engineering students. The platform will be available to students throughout their undergraduate experience, enable easier engagement with the competencies, and also gather students' experiences and reflections over time to assist with upper-level synthesis—similar to some features of an electronic portfolio.

The work in ENGR 490 and AERO 495 are providing useful insights for how students can engage with the competency resource through the platform. For example, the scoring that was developed for AERO 495 is guiding our design plans for how the platform could measure student progress over time. Also, the instructor's approach to work with a specific subset of competencies in the class has helped us ensure the appropriate platform flexibility for instructors who would like to emphasize particular competencies with a course. And the activities developed for ENGR 490 around the preparation of professional documents are informing our thinking about how students could use the platform to prepare materials (e.g., professional statements, resumes) which reflect their competency development. We continue to explore other pathways to promote the framework and are currently preparing a workshop for 30 faculty that will involve each participant creating a plan for utilizing framework resources with either a course or co-curricular experience.

References

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

[2] Cantor, J. Experiential Learning in Higher Education: Linking Classroom and Community. *ASHE-ERIC Higher Education Report No. 7,* 1994.

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

[4] National Academy of Engineering, Educating the engineer of 2020: Adapting Engineering Education to the New Century. Washington, D.C: The National Academies Press, 2005.

[5] C. J. Atman et al., "Enabling Engineering Student Success," *Cent. Adv. Eng. Educ.*, 2010.

[6] "Infusing Real World Experiences into Engineering Education," Washington D. C, 2012.

[7] American Society for Engineering Education, "Transforming Undergraduate Education in Engineering," 2013.

[8] National Academy of Engineering, Educating Engineers: Preparing 21st Century Leaders in the Context of New Modes of Learning. Washington, D.C.: National Academy Press, 2013.

[9] Harrisberger, L., & others. *Experiential Learning in Engineering Education. American Society for Engineering Education*, 1976.

[10] Fisher, D. R., Bag, A., & Sarma, S. Developing Professional Skills in Undergraduate Engineering Students through Co Curricular Involvement. *Journal of Student Affairs Research and Practice*, *54,* 3, pp. 286–302, 2017. https://doi.org/10.1080/19496591.2017.1289097

[11] Simmons, D. R., Creamer, E. G., & Yu, R. Involvement in Out of Class Activities: A Mixed Research Synthesis Comparing Outcomes of Engineering to Non- engineering Undergraduate Students. *Journal of STEM Education: Innovations and Research*, 18, 2, 2017.

[12] Conger, A. J., Gilchrist, B., Holloway, J. P., Huang-Saad, A., Sick, V., and Zurbuchen, T. H. Experiential Learning Programs for the Future of Engineering Education. *IEEE Transforming Engineering Education: Creating Interdisciplinary Skills for Complex Global Environments*, pp. 7–13, 2010. https://doi.org/10.1109/TEE.2010.5508822

[13] Woodcock, C. S. E., Callewaert, J., and Millunchick, J., "Synthesizing Definitions of Professional Competencies Linked to Experiential Learning in Engineering Education: A Literature Review," *J. High. Educ. Theory Pract.*, vol. 21, no. 4, 2021.

[14] Callewaert, J. Experiential Learning Framework. Retrieved December 7, 2020, from https://adue.engin.umich.edu/experiential-learning-framework/

[15] Callewaert, J., Millunchick, J., Woodcock, C., Jiang, K., and Edington, S., "Developing a Framework for Experiential Learning," in American Society for Engineering Education Annual Conference and Exposition, 2020.

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

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

[18] Burning Glass Technologies, "The Human Factor: The Hard Time Employers have Finding Soft Skills," 2015 [Online]. Available: https://www.burning-glass.com/wp-content/uploads/Human_Factor_Baseline_Skills_FINAL.pdf. [Accessed 19-Jan-2020].

[19] Automation Alley, Technology in Industry Report 2019, Industry 4.0: From Vision to Implementation, https://automationalley.com/Knowledge-Center/Technology-in-Industry-Report.aspx [Accessed 2-Apr-2020].

[20] Green, H. E. Use of Theoretical and Conceptual Frameworks in Qualitative Research. *Nurse Researcher*, *21,* 6, pp. 34–38, 2014.

[21] Kolb, A. Y., & Kolb, D. A. Experiential Learning Theory: A Dynamic, Holistic Approach to Management Learning, Education and Development. In *The SAGE Handbook of Management Learning, Education and Development,* 2009. https://doi.org/10.4135/9780857021038.n3

[22] Kolb, D. A. *Experiential Learning: Experience as the Source of Learning and Development, 1984*. Englewood Cliffs, NJ: Prentice Hall. https://doi.org/doi:10.1016/B978-0-7506-7223-8.50017-4

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

[24] Kolb, David A., Boyatzis, R. E., & Mainemelis, C. Experiential Learning Theory: Previous Research and New Directions. In *Perspectives on Thinking, Learning, and Cognitive Styles*, 2011. https://doi.org/10.4324/9781410605986-9

[25] R. M. Meertens and R. Lion, “Measuring an Individual’s Tendency to Take Risks: The Risk Propensity Scale,” J. Appl. Soc. Psychol., vol. 38, no. 6, pp. 1506–1520, 2008.

Appendix A: 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.

Appendix B1: Example Rubric for Teamwork Competency - Learning Outcomes

	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.

Appendix B2: Example Rubric for Teamwork Competency - Reflection Prompts and Assessment Indicators

<table>
<tr><th></th><th>Exploring (1)</th><th>Engaging (2)</th><th>Explaining (3)</th></tr>
<tr><td rowspan="2">Valuing the Development of Shared Rules, Norms, Structure</td><td colspan="3">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?</td></tr>
<tr><td>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.</td><td>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.</td><td>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.</td></tr>
<tr><td rowspan="3">Recognition of and Commitment to a Common Purpose / Goal</td><td colspan="3">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?</td></tr>
<tr><td rowspan="2">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.</td><td rowspan="2">I: The student's response focuses on their actions towards the goal of the project, and acknowledges others' contributions.</td><td>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.</td></tr>
<tr><td>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.</td></tr>
</table>

<table>
<tr><td rowspan="2">Ability to Work Across Disciplinary Differences</td><td colspan="3">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?</td></tr>
<tr><td>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.</td><td>I: The student gives an example of when an engineer might work with different disciplines and discusses value in terms of tasks/skills/ knowledge associated with various disciplines.</td><td>I: The student gives an example of when an engineer might work with different disciplines and discusses value in terms of communication and collaboration with other disciplines as a means to learn.</td></tr>
<tr><td colspan="4">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.</td></tr>
</table>

Appendix C: Questions asked as part of the Post-Course Interviews with ENGR 490

- Which aspects of this course were most helpful to your professional development?
- Which aspects of this course were least helpful to your professional development?
- Did the class meet your expectations? If not, why?
- Were you able to utilize reflective learning skills in order to reach deeper levels of self-awareness and professional competency development in this course? If so, how?
- Were you able to connect your values and goals through this class? If so, how?
- In order to improve this class I feel that there should be more...
- In order to improve this class I feel that there should be less...
- What would have made you more prepared?
- Any other comments?

Appendix D: Pre-Course and Post-Course Surveys from AERO 495

Questions were the same from the pre-and post-course survey with adjustments made to reflect whether students were starting or finishing the semester. Definitions referenced are those found in Appendix A.

Teamwork

- Keeping in mind the definition of teamwork provided, how would you define success for your team? What will make the team successful this semester?
- Keeping in mind the definition of teamwork provided, what is it like working in a team with engineers who are different from you (e.g. different disciplines, gender identities, race/ethnicities, educational backgrounds)? What do you think you will find valuable about that experience? What do you anticipate being difficult?
- Thinking about your in-class and out-of-class experiences with teamwork, please rate your ability (1-5; 1 = no ability; 5 = high ability) to do the following:
  - Work in teams where knowledge and ideas from many disciplines (business, public policy, engineering, etc.) must be applied.
  - Work in teams where knowledge from many engineering disciplines must be applied.
  - Collaborate with others when working on multidisciplinary teams.
  - Communicate effectively with others when working on multidisciplinary teams.
  - Effectively manage conflicts that arise when working on multidisciplinary teams.
  - Do your fair share of the work when working on multidisciplinary teams.

Leadership

- Keeping in mind the definition of leadership provided, can you give an example of a situation where an engineer might use their leadership skills in a team setting? How would you identify an engineer-leader in a team setting?
- Keeping in mind the definition of leadership provided, what goals does your student organization have this semester? How might you go about contributing to them?
- Thinking about your in-class and out-of-class experiences with leadership, please rate your ability (1-5; 1 = no ability; 5 = high ability) to do the following:
  - Help your group work through periods when ideas are too many or too few.
  - Develop a plan to accomplish a group or organization's goals.
  - Take responsibility for group's or organization's performance.
  - Motivate people to do the work that needs to be done.
  - Identify team members' strengths/weaknesses and distribute tasks and workloads accordingly.
  - Monitor the design process to ensure goals are being met.

Managing Risk

- Keeping in mind the definition of managing risk provided, when would you be willing to take a risk or accept a decision you considered risky in an engineering design project?
- Keeping in mind the definition of managing risk provided, how might you justify a design decision that has associated risk? In other words, how do you know you are managing or mitigating risk rather than just acknowledging it?
- Thinking about your in-class and out-of-class engineering experiences with managing risk, please rate your agreement (1-5; 1= strongly disagree; 5 = strongly agree) with the following statements related to risk:
  - Safety first.
  - I prefer to avoid risks.
  - I take risks regularly.
  - I really dislike not knowing what is going to happen.
  - I usually see risks as a challenge.
  - I view myself as a risk seeker.

Systems Thinking

- Keeping in mind the definition of systems thinking provided, think about how you work on your project, by yourself or with the team. Then tell us about the process. For example, how you solve problems, figure out the next step, or simply get things done.
- Keeping in mind the definition of systems thinking provided, how do you determine if you have met the goals of a project? If there are multiple goals, how do you prioritize them?
- Thinking about your in-class and out-of-class experiences with systems thinking, please rate your ability (1-5; 1 = no ability; 5 = high ability) to do the following:
  - Integrate knowledge and skills learned in engineering disciplines other than your specific major.
  - Recognize the need to consult an expert from a discipline other than your own when working on a project.
  - Recognize the limitations or validity of other professional engineers' opinions.