ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE
Paper ID #37748

Assessing Multidisciplinary, Long-Term Design Experiences

William C. Oakes (Director and Professor)

William (Bill) Oakes is a 150th Anniversary Professor, Director of the EPICS Program, Professor of Engineering Education at Purdue University, and a registered professional engineer. He is one of the founding faculty in the School of Engineering Education having courtesy appointments in Mechanical, Environmental and Ecological Engineering and Curriculum and Instruction. He was the first engineer to receive the U.S. Campus Compact Thomas Ehrlich Faculty Award for Service-Learning and a co-recipient of the U.S. National Academy of Engineering's Bernard Gordon Prize for Innovation in Engineering and Technology Education. He is a fellow of ASEE and NSPE.

Paul Leidig

Paul A. Leidig is a PhD candidate in Engineering Education and a member of the instructional team for the Engineering Projects In Community Service (EPICS) program at Purdue University in West Lafayette, Indiana. He received his Bachelors of Science in Architectural Engineering from the Milwaukee School of Engineering and Masters of Science in Civil Engineering from the University of Illinois at Urbana-Champaign. Mr. Leidig is licensed as a Professional Engineer in the state of Colorado and has six years of structural engineering consulting experience. He currently consults on learning and talent development programs within the architecture, engineering, and construction industry. Mr. Leidig has focused on community-engaged engineering and design for over fifteen years.

Andrew Pierce (Laboratory Manager)

Assessing Multidisciplinary, Long-Term Design Experiences

Introduction

Community-engaged design experiences offer many benefits to engineering, the design community, and higher education in general. These experiences offer opportunities for students to engage with real users and to see how designs can positively impact people, the environment, and communities locally and globally. Community-engaged learning offers a context to support the broad learning needed for the 21st century engineer [1-6]. The pedagogy has shown benefits to student learning [7-10], motivation and retention [11-13]. Additionally, evidence shows that community-engagement can improve diversity within engineering programs [14-16]. With these benefits and the possibilities for impacting engineering programs, assessment methods are needed to support the open-ended design experiences they incorporate.

Design experiences, including those encapsulated within community engagement efforts, are increasing within engineering curricula and traditional assessments including quizzes, homework problems, and exams are not typically applicable in these settings. Often, assessment schemes are set up based on expected deliverables and project completion. Approaches that heavily weight project milestones and completion can be effective within a single-term or single-year experience where the design is expected to be completed on a pre-set schedule. These methods do not work as well in more open-ended design experiences where student teams may be at different points in their design at varying point throughout the academic year. Additionally, if design project work spans multiple academic terms or years, the types of deliverables that can be assessed vary significantly between teams. This happens frequently within community-engaged design experiences, where designs are developed with community partners and the design process involves iteration based on the partner feedback and testing.

To fill our perceived gap in published appropriate assessment instruments for use in this space, an assessment method is presented that has been developed for a large design-based community engagement program, which allows student learning to be evaluated at scale, in any stage of the design process, and through their various roles on the design team. The methodology is adapted from industry models and tailored to the design-based community-engaged learning context to promote learning and the reciprocal community partnerships.

Program Overview

In the EPICS program, teams of undergraduates partner with local or global not-for-profit community organizations to define, design, build, test, deploy, and support engineering-centered projects that significantly improve the organization's ability to serve the community. Created 25 years ago and developed with NSF support, it integrates highly mentored, long-term, large-scale, team-based, multidisciplinary design projects into the undergraduate engineering curriculum. Students can participate multiple semesters, and teams typically have a mix of returning and new

students on the team. Students take on different roles, such as design lead, project manager, and project partner liaison. The core of the EPICS courses is the design work with their community partner and it is supplemented with required professional development hours (PDHs) outside of the regular class period that are selected from many offerings. EPICS has grown at Purdue University to 45 divisions with over 1200 students participating each year representing more than 30 majors from all colleges within the university. Students include first-year students to seniors with each taking the course for different types of credit within their respective degree program. Each section has a theme of a common community partner or technology, having an average of 15 students with 2-4 project teams within each section. The large section size helps insure some returning students each semester for continuity of projects across terms. Community partners are engaged with a minimum commitment of five years and most partnerships continuing for more than a decade. In the spring of 2019, 42% of the participants were female, while 43% of the participants were non-Caucasian. First-year students participate through the EPICS Learning Community, which has averaged 43% female over the last six years. EPICS leads a university consortium that has engaged more than 50 other institutions globally in developing similar course structures as well as a K12 Program that brings EPICS projects in more than 100 middle and high schools in 17 states within the U.S.

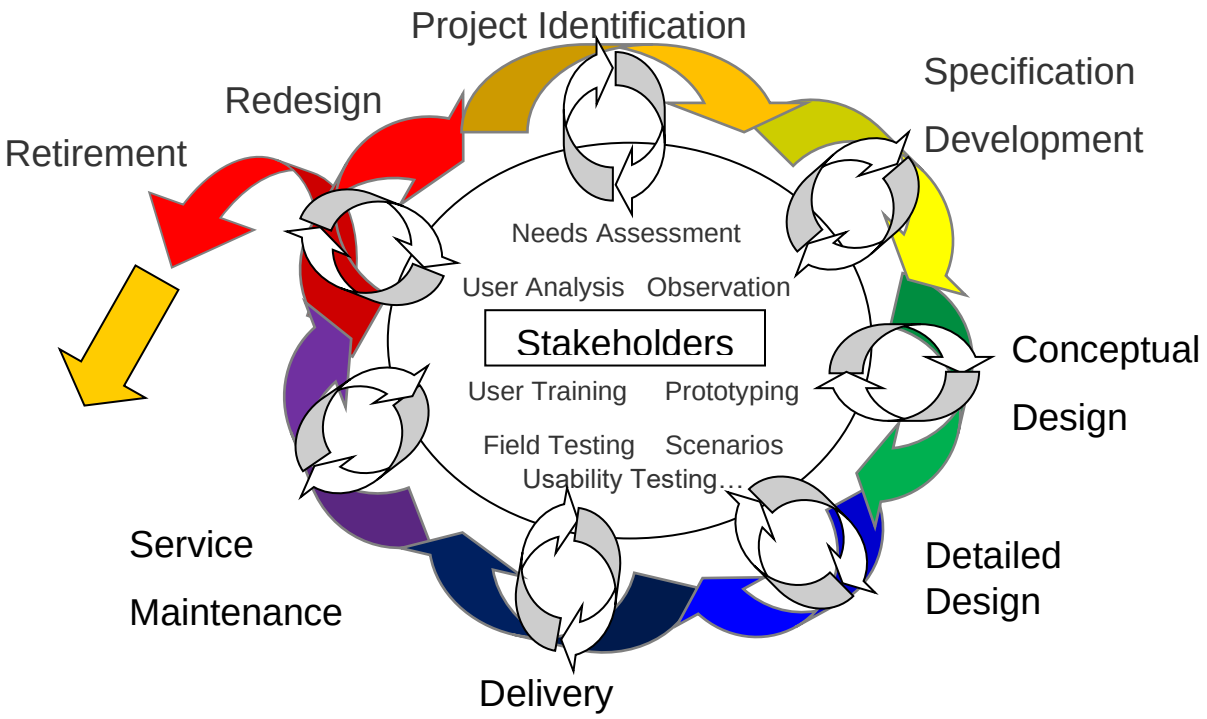


FIGURE 1. EPICS DESIGN PROCESS MODEL

While there is not a single model for design, the program teaches a common design process that is applicable for community-based designs, to provide a common process and structure across the more than 100 project teams within the program. The design process was developed to reflect a human-centered perspective where stakeholders are at the heart of the approach to

community-engaged design. Stakeholders include all of those who are impacted by the project, including the direct users, the community partner organization, secondary users (such as teachers, therapists, and people who maintain the project), parents and family members, as well as the broader communities that each of these stakeholders represent. The EPICS design process begins with understanding the needs of the stakeholders and involves them throughout the design process. It is iterative and advocates the use of prototypes and empirical evaluation to make design decisions. It also includes attention to the delivery, service, and maintenance aspects of the project. [17]

The overall philosophy of EPICS is guided by the core values that balance student learning and preparation for life after graduation with community partnerships and impact. EPICS is academically a design course that is done within the context of community engagement which offers rich opportunities for authentic design projects and opportunities for broad learning and impact on people, communities, and the environment. A model that represents EPICS is shown in Figure 2, with the Venn diagram's three circles representing domains of the student experience and learning in multi-disciplinary design, professional preparation, and community-engaged learning. The intersection of these three domains is the EPICS experience. Each impacts the assessment philosophy and methodology.

The first area is design and in particular multidisciplinary design. In a typical year, students from nearly 30 majors will participate and most teams are highly multidisciplinary. The second domain involves professional preparation. One of the original goals when EPICS was created in the mid 1990's was to prepare students for professional practice. This goal remains today guiding the environment and methods used in the course that are explicitly designed to cultivate professional habits and expose students to aspects of professional work. Research findings show that EPICS is effective in that work [18,19]. The final domain is the broader learning that arises from the community-engagement and partnerships. It is expected that student will learn about their partners and the context in which they work. Aspects of the experience, including guided reflections, are intended for students to explore the opportunities for community impact within their respective disciplinary lens.

Assessment Philosophy

The philosophy of the assessment is that it compliments and enhances the overall program goals and contributes to the learning, project development and partnerships where possible. It must align with and capture the richness of the community-engagement experience without placing undo burdens on students, faculty, or community partners. To align with the goals of the program and capture the richness of the learning experience, it can be broken down into components shown in Figure 2

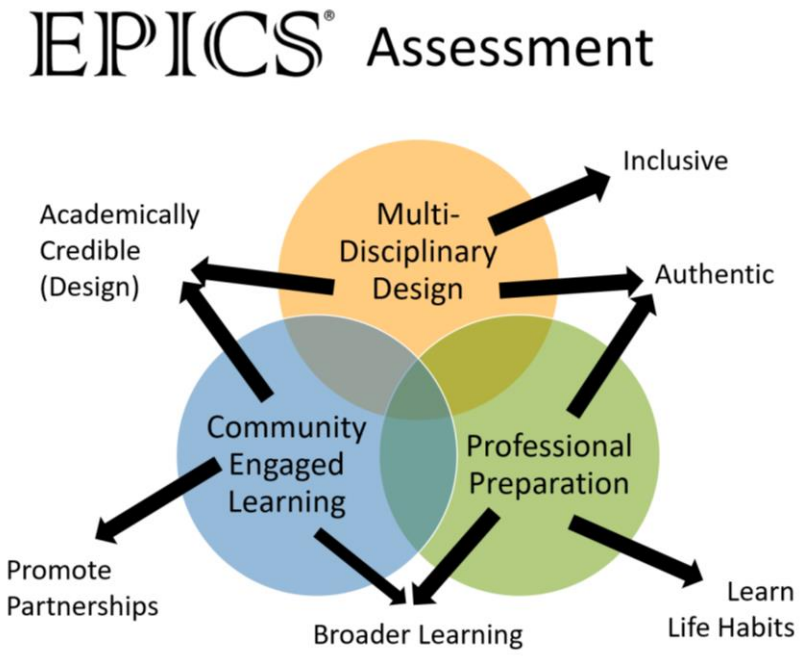


Figure 2: Content Domains and Assessment Attributes

1) Academically credible: Assessment must be credible for faculty colleagues, university guidelines and procedures and for accreditation. The comparisons and guardrails are benchmarked with other design and experiential learning experiences with the college and across the university.
2) Inclusive: EPICS draws diverse students in many ways. Teams are vertically integrated, first-year to final year, and multidisciplinary, across and beyond engineering. Additionally, the projects are not connected to the semester timeline, so students may be working on different parts of a project and in different phases of the design at any given time.
3) Authentic: A key attribute of the program is that all projects are real projects that will be delivered to their community partners when completed. Assessments should flow from the project development where possible and align with professional habits that will be useful later in their careers.
4) Life Habits: Assessments should develop skills, provide experiences, and promote habits that will make the students better professionals, citizens, and people.
5) Broader Learning: While design is a core content domain, the community-engaged learning experience offers a plethora of opportunities for broader learning about themselves, their careers, their community partners, broader society, and connections between these and their discipline.
6) Promote Partnerships: Community-engaged learning should promote reciprocal and mutually beneficial partnerships that include learning amongst students,

faculty, and community partners. It should also promote the long-term engagement with the program and honor the relationships that are developed.

While assessment cannot and is not intended to play these roles by itself, the assessment strategy should promote these attributes. Where possible, assessments are imbedded into the work of the project and the team.

Assessments of students in EPICS consider an individual's holistic body of work in the context of a larger team environment. The assessment process is designed to accommodate students from different majors working in different phases of the design process and in different roles. The assessment practices are also intended to follow the form of personnel performance reviews in industry, to help equip students to thrive in their careers after graduation. Each student is evaluated on five outcome criteria:

1. Accomplishments,
2. Design Process,
3. Reflective and Critical Thinking,
4. Teamwork or Leadership,
5. Communication.

The first step in the assessment process is for students to establish their goals and expectations for the semester. They do this with the faculty member who oversees their specific section. Once the goals have been established, progress toward the goals is documented in an electronic notebook using OneNote. The notebooks are divided into sections that aligned with the evaluation criteria.

Students are assessed at three formal times over the fifteen-to-sixteen-week semester. At week four in the semester, feedback is given on their progress and quality of their documentation. The main objective is to ensure the students are creating sufficient documentation that can be assessed in the more comprehensive stages later in the semester. The quality and quantity of documentation often needs coaching at this stage for students new to the experiential learning environment. Reflection is another area that typically needs feedback currently, to guide students.

At the midpoint in the semester, a full grading is done using the assessment process. Students complete the Individual Evaluation Rubric (IER), described below, where they rate themselves against the five evaluation criteria and point to the documentation that supports their evaluation. This helps guide the instructional team to find the appropriate documentation. The students also evaluate each other using the CATME evaluation system [20]. Students are given a grade along with comments on what they can do to improve. Short discussions are held with each student about their performance, the quality of the documented evidence of their performance, and guidance on how to achieve their desired grade if they are not satisfied with the formative evaluation.

Some students will receive feedback at week 12 if there were issues that need to be addressed as another formative feedback.

At the end of the semester, the grading process is repeated with students completing another version of the IER and peer evaluations. The holistic process is repeated. Since students were given comments and grades at the mid semester, the formative feedback is used as a baseline for final grading.

Development of the Individual Evaluation Rubric (IER)

The EPICS assessment process involving the IER has been used for several years, [19] but in 2018, the approach was revised. Earlier versions of the IER had separate rubrics for first- and second-year students. The previous intent was that third- and fourth-year students would be more mature and would also be able to apply disciplinary expertise to the projects. This method worked well but there was more judgement needed from the various advisors (instructors) and more variability in the grading process than was desired. The methodology to develop a more consistent and structured process followed the model of a modified Delphi method where input was sought from the instructors and other stakeholders. Drafts of a new rubric were created and feedback sought from the advisors again until the rubric was created. The issues that the changes sought to address were:

1) One common rubric for all students
2) More objective criteria for determining the grades, which would provide more consistency across different divisions.
3) A one- or two-page grading rubric and summary for ease of use
4) Accounting for learning, project work, and expected items like attendance and submission of required documents

The common rubric was created with iterations from a core team of volunteers from the faculty. The common rubric is shown in Appendix A along with the instructions and assessment pages for the IER. While the rubric is common, the grading criteria for first, second, third-, and fourth-year students is different and reflects the expectations of students maturing as they progress in their ability to apply their respective disciplinary expertise to the project work. The revised rubric also explicitly held students accountable for the academic components and assignments of the course. The revisions have provided more structured and consistent means for students and instructors to evaluate artifacts that demonstrate mastery of outcomes and activities. The university employs plus and minus grading, which offers flexibility within the grading for adjustments made based on observation and work that does not fit exactly into the rubric.

The rubric is common, but the expectations change for students at different academic levels (e.g., first-year, sophomores, juniors, or seniors). The approach was that for a senior to receive a grade of an A, they needed to show excellence in a majority of the evaluation categories and have at least proficient competency in each. Thus, the choice of three excellent and two proficient. For first-year students, the expectation is that they may be assisting more senior students and

adjusting to the level of work expected in college. Proficient was viewed as sufficient for an A. The logical progressions followed that in year two students would demonstrate one excellent and in year three two. The comparison of the grading criteria by year in shown in Table 1.

Table 1: Rubrics for Each Academic Year (E = Excellent, P = Proficient, C = Competent)

Grade	1st Year	2nd Year	3rd Year	4th Year
A	• P or better in 3 outcomes, C or better in 2 • No unexcused absences • Team and individual requirements complete • All PDHs complete	• E in 1 outcome, P or better in 2 outcomes, C or better in 2 outcomes • No unexcused absences • Team and individual requirements complete • All PDHs complete	• E in 2 outcomes, P or better in 2 outcomes, C or better in 2 outcomes • No unexcused absences • Team and individual requirements complete • All PDHs complete	• E in 3 outcomes, P or better in 2 outcomes • No unexcused absences • Team and individual. requirements complete • All PDHs complete
B	• P or better in 3 outcomes, C or better in 2 outcomes • No more than one unexcused absence • Team and individual requirements complete • All PDHs complete	• P or better in 3 outcomes, C or better in 2 outcomes • No more than one unexcused absence • Team and individual requirements complete • All PDHs complete	• P or better in 3 outcomes, C or better in 2 outcomes • No more than one unexcused absence • Team and individual requirements complete • All PDHs complete	• P or better in 3 outcomes, C or better in 2 outcomes • No more than one unexcused absence • Team and individual requirements complete • All PDHs complete
C	• C or better in all outcomes • No more than two unexcused absences • More than half of the team and individual requirements complete	• C or better in all outcomes • No more than two unexcused absences • More than half of the team and individual requirements complete	• C or better in all outcomes • No more than two unexcused absences • More than half of the team and individual requirements complete	• C or better in all outcomes • No more than two unexcused absences • More than half of the team and individual requirements complete

	• At least 60% of PDH hours completed	• At least 60% of PDH hours completed	• At least 60% of PDH hours completed	• At least 60% of PDH hours completed
D	• C or better in 3 outcomes • No more than three unexcused absences • At least 40% of PDH hours completed	• C or better in 3 outcomes • No more than three unexcused absences • At least 40% of PDH hours completed	• C or better in 3 outcomes • No more than three unexcused absences • At least 40% of PDH hours completed	• C or better in 3 outcomes • No more than three unexcused absences • At least 40% of PDH hours completed
F	Fails to meet D requirements	Fails to meet D requirements	Fails to meet D requirements	Fails to meet D requirements

Reflection

Reflection is a key component of the pedagogy of community-engaged learning and has become more widespread within the design community. It is also the component of the EPICS assessment process that has evolved most recently and can be challenging to nurture and assess. In summer 2020, an effort was made to refine the EPICS approach to reflection, its support, and assessment. This work was led by an engineering education graduate student who is part of the program instructional team and involved the active participation of several others from the leadership and instructional team. A review of the literature and best practices was performed and resulted in a recommendations document which was iteratively revised based on feedback from the larger team. Once consensus was reached, the primary graduate assisdtant compiled a set of program recourses to implement the new practices, which included updated student instructions and language for the program website, sample reflections with representative feedback, and a TA training document on the topic. Samples of the example reflections provided to students can be found in Appendix B.

The motivation for this effort was driven by a desire to create more clear expectations for both students and graders. Such clarity supports student achievement of the relevant learning outcome and a procedural sense of fairness, while also reducing time and frustration spent on the grading process and supporting consistent grading between EPICS sections. The elements considered included the reflection content components and themes. The outcome competencies listed in the IER are based on the Kolb learning cycle [21]. Following Kolb's framework, the concrete experience occurs for the student while participating in the activities of the projects; then, the reflection prompt below scaffolds the students in progressing through the steps of reflective observations, abstract conceptualization, and active experimentation.

Three content components for EPICS reflections:

- Reflective observation of your experience during the week to spark this reflection (Consider: identifying an experience and its context and/or impact).

- Conceptualizing and connecting your observation to a broader concept in one of the reflection themes (Consider: What did I learn? How did I learn it? Why does the learning matter?).
- Connecting how you will use your experience and learning in the future, inside and outside EPICS (Consider: What will/could I or others do in light of this learning?).

The four reflection themes remain personal and professional development, social impact, academic enhancement, and ethics. Based on pervious student feedback that some have had trouble thinking of specific reflection topics to address in the past, the current instructions provide a substantial number of inspiration questions. They are meant to help spark a reflection framing but are not required to be addressed or answered exactly as written. These questions were partially based on the work of Ash and Clayton [22]. Below are the inspiration questions for one of the themes.

Personal and Professional Development:

- What did I learn about who I am (my strengths, weaknesses, skills, etc.) and who I want to become, personally or professionally?
- What assumptions or expectations did I bring to the situation? How did they affect what I did or did not think, feel, decide, or do? To what extent did they prove true? If they did not prove true, why was there a discrepancy?
- How did this situation challenge or reinforce my values, beliefs, convictions (e.g., my sense of right and wrong, my priorities, my judgments)? My sense of personal identity?
- What is/should be the role of partnership, reciprocity, and/or co-design in my work? What have I learned from the community partner, and what resources have they provided to the project process and deliverable?
- What role does/should empathy play in my work?

The consideration of reflection frequency was also initiated by the EPICS administration to confirm alignment with best practices, as documented in the literature. Ultimately, the question of frequency tied back to the work of John Dewey and his calls for continuous reflection for learning [23]. As the program guides the EPICS students towards such reflective practices, it requires proof of reflection at the most frequent interval practically possible, which has been determined to be on a weekly basis. In addition to this, an end of semester reflection is assigned to review the course experience upon its conclusion.

Capstone Design

EPICS projects are well-matched to the revised ABET criteria and many of our projects present opportunities to achieve the criteria required for senior design. However, the variation in EPICS student's project application spaces and interaction points within the design process of the larger overall program present challenges in insuring appropriateness of individual fit for capstone design. EPICS projects can currently be used for capstone design in Electrical, Computer, Multidisciplinary, or Environmental and Ecological Engineering, but each program's department follows a slightly different process for approval and assessment on top of the common EPICS elements. Not every project meets the criteria for capstone. A member of the EPICS leadership team serves as the lead for the capstone courses, ensuring project opportunities are surveyed each

semester and that students interested are funneled through a gateway check to insure appropriateness of the fit for their respective major.
.
Typically, the capstone design experience is two semesters in EPICS, even though it can be a single semester in some disciplines. Four documents are integrated into the assessment process to track progress and completion. These documents, shown in appendix C, are

1. Project Proposal is an individual document that is completed by the student and approved by the team advisor. It provides early feedback on project appropriateness including whether the project is a significant design experience on a suitable project and describes how the student plans to demonstrate mastery of each outcome.
2. Outcomes Matrix is an individual document where students document that all outcomes were achieved over the two-semester experience. It is more comprehensive and specific than the IER. Students must achieve the outcomes specified by their respective major to receive a passing grade.
3. Project Description is a document that describes the work completed on the project and summarizes how the outcomes have been met across all senior design students on the team. These are reviewed by the capstone committees in the respective departments. The reports are part of the EPICS evaluation process and are forwarded to the departments after the semester. Evaluation of the reports is done as part of the continuous improvement process for capstone design.
4. Final Reflection is a document where each senior design student discusses their personal contributions to the project and describes how their contributions built on the knowledge and skills, they acquired in their earlier course work. This is also where they reflect on their learning strategies, their ethical and professional responsibilities, and the impact of their engineering design experience could have on economic, environmental, societal, and global contexts. This document is also included in the evaluation reports forwarded to the departments after the semester as part of the continuous process for capstone design.

Discussion and Conclusion

The goal of the paper was to share the assessment strategy, instruments and development process with the broader design education community. This assessment process has proven effective for measuring student achievement of course learning outcomes in alignment with the course philosophy, including in the cases of senior design, despite the constrains and complexities of the community-engaged design model with long-term community partnerships. The approach has also proved operational at scale, allowing the program to grow in size and type of project over time while maintaining consistency in assessment techniques. The inclusive and academic credibility of the assessments has aided the inclusion of many disciplines and the program has grown to where students from any college in the university can take the courses and count them in some manner towards graduation. Students can use the program as an alternate pathway through the first-year engineering courses. The university counts the course as an option for the university core requirements. The entrepreneurship certificate allows the courses to be included in their program. Students from four engineering programs and several other departments allow seniors to use it as an alternative for the capstone.

Data from alumni attest to the impact that the program has including the assessment processes. They reported that participation in the program improved their ability to transition into professional practice [18,19].

There are many benefits of to community engagement and service-learning and design courses are the most common place for the pedagogy to be implemented in engineering. The availability of a well-performing assessment approaches, like the one presented here, is critical to allowing for such programs to proliferate and grow. Future work will continue in refining the process and adapting to improve the reliability and validity of the assessment results. It is also a goal to have more programs test out this assessment methodology and report findings; getting more participation in the program from around the university and elsewhere; ongoing continuous improvement efforts in the home program.

References

1. B. Jaeger, & E. LaRochelle, E.. EWB – "Engineers Without Borders: Educationally, a world of benefits" . 2009 *American Society for Engineering Education (ASEE) Annual Conference Proceedings*, Paper AC 2009-740, Austin, TX, 2009.
2. E. J. Coyle, L.H., Jamieson, W. C., Oakes, "EPICS: Engineering Projects in Community Service", *International Journal of Engineering Education* Vol 21, No. 1, Feb. 2005, pp. 139-150.
3. J. L. Huff, C. B. Zoltowski, and W. C. Oakes, "Preparing Engineers for the Workplace through Service Learning: Perceptions of EPICS Alumni", ", *Journal of Engineering Education*, Vol. 105, No. 1, January 2015, pp. 43-69
4. A. R. Bielefeldt, K. Paterson, C. Swan Measuring the value added from service learning in project-based engineering education. *International Journal of Engineering Education, 26*(3), 2010, pp. 535-546.
5. O. Pierrakos, R. Nagel, E. Pappas, J. Nagel, T. Moran, E. Barrella, E., et al. . A mixedmethods study of cognitive and affective learning during a sophomore design problembased service learning experience. International Journal for Service Learning in Engineering, Special Edition(Fall), 2013, pp. 1-28.
6. K. Litchfield, A. Javernick-Will, and A. Maul. "Technical and professional skills of engineers involved and not involved in engineering service." *Journal of Engineering Education* 105.1, 2016, pp. 70-9
7. Eyler, Janet, "Reflection: Linking Service and Learning—Linking Students and Communities", Journal of Social Issues, Vol. 58 Issue 3, 2000, Pages 517 – 534
8. D. E. Giles, & J. Eyler, The impact of a college community service laboratory on students' personal, social, and cognitive outcomes. *Journal of Adolescence*, *17*, 1994, pp. 327–339.
9. Eyler, J., & Giles, D.E. *Where's the learning in service-learning?* San Francisco: Jossey-Bass, 1999.
10. A. W. Astin, L. J. Sax & J. Avalos, J. Long-term effects of volunteerism during the undergraduate years. *Review of Higher Education, 22*(2), 1999, pp. 187–202.
11. Oakes, William, James Huff, Carla B. Zoltowski, and Devendra Canchi. "Impact of the EPICS model for community-engaged learning and design education." *The International journal of engineering education* 34, no. 2, 2018, pp. 734-745

12. L. Piket-May, and J. Avery, Service-learning First Year Design Retention Results, *ASEE/IEEE Frontiers in Education Conference*. October 10-13, 2001, Reno, NV.

13. B. Ropers-huilman., Carwile, L., and Lima, M. "Service-learning in engineering: a valuable pedagogy for meeting learning objectives", *European Journal of Engineering Education*, Vol. 30, No. 2, pages 155 - 165

14. H.M. Matusovich, W. Oakes, C. B. Zoltowski, Why women choose service-learning: Seeking and finding engineering-related experiences. International Journal of Engineering Education, Vol. 29, No. 2, 2013, pp. 388-402.

15. W. C. Oakes, M. C. Hsu, C. B., Zoltowski, Insights From A First-Year Learning Community To Achieve Gender Balance, *Proceedings of the 2015 Frontiers in Education Conference*, El Paso, Texas, October 2015.

16. B. Jaeger, & E. LaRochelle, E.. EWB^2 – Engineers Without Borders: Educationally, a world of benefits. *American Society for Engineering Education (ASEE) Annual Conference Proceedings*, Paper AC 2009-740,,

17. Cummings, A., Huff, J., Oakes, W. and Zoltowski, C., "An Assessment Approach to Project-Based Service Learning", *Proceedings of the 2013 ASEE Annual Conference*, Atlanta, GA, June 2013

18. Huff, J., Zoltowski, C., Oakes, W., and Adams, R., "Making Sense of Design: A Thematic Analysis of Alumni Perspectives", *Proceedings of the 2013 ASEE Annual Conference*, Atlanta, GA, June 2013

19. Huff, James L., Zoltowski, Carla B., and Oakes, William C., "Preparing Engineers for the Workplace through Service Learning: Perceptions of EPICS Alumni", *Journal of Engineering Education*, Vol. 105, No. 1, January 2015, pp. 43-69

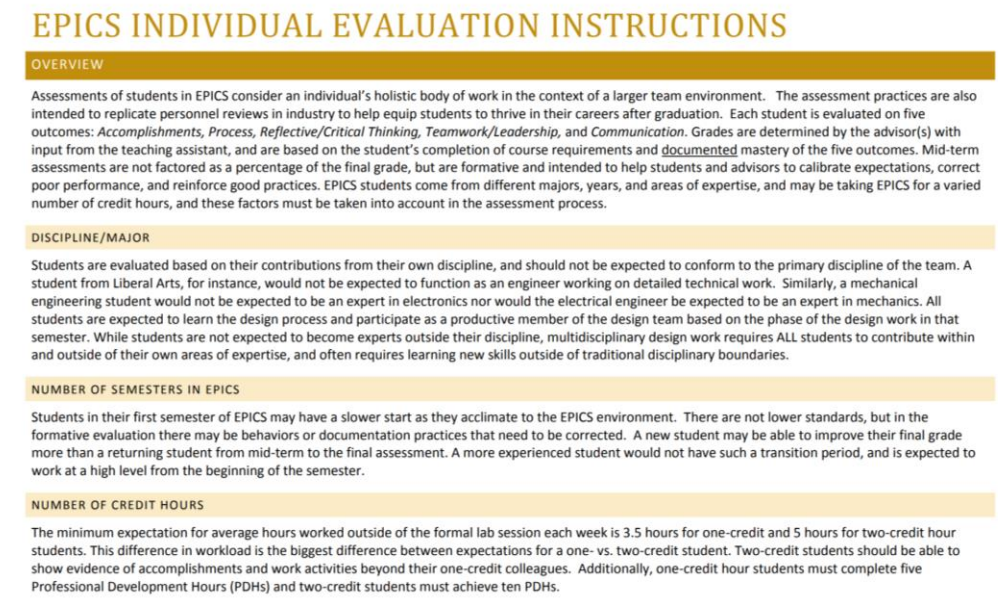
20. https://catme.org/login/index, accessed 3/8/2021

21. Ash, S. L., & Clayton, P. H. Generating, deepening, and documenting learning: The power of critical reflection in applied learning. Journal of Applied Learning in Higher Education, 1(1), 2009, pp 25-48.

22. Dewey, J. Experience and education. Touchstone Books Simon and Schuster. New York, NY. 1938.

23. Kolb, D. A. Experiential learning: Experience as the source of learning and development. Englewood Cliffs, NJ: Prentice Hall, 1984.

Appendix A – Individual Evaluation Rubric



EPICS INDIVIDUAL EVALUATION INSTRUCTIONS

OVERVIEW

Assessments of students in EPICS consider an individual's holistic body of work in the context of a larger team environment. The assessment practices are also intended to replicate personnel reviews in industry to help equip students to thrive in their careers after graduation. Each student is evaluated on five outcomes: *Accomplishments, Process, Reflective/Critical Thinking, Teamwork/Leadership,* and *Communication*. Grades are determined by the advisor(s) with input from the teaching assistant, and are based on the student's completion of course requirements and documented mastery of the five outcomes. Mid-term assessments are not factored as a percentage of the final grade, but are formative and intended to help students and advisors to calibrate expectations, correct poor performance, and reinforce good practices. EPICS students come from different majors, years, and areas of expertise, and may be taking EPICS for a varied number of credit hours, and these factors must be taken into account in the assessment process.

DISCIPLINE/MAJOR

Students are evaluated based on their contributions from their own discipline, and should not be expected to conform to the primary discipline of the team. A student from Liberal Arts, for instance, would not be expected to function as an engineer working on detailed technical work. Similarly, a mechanical engineering student would not be expected to be an expert in electronics nor would the electrical engineer be expected to be an expert in mechanics. All students are expected to learn the design process and participate as a productive member of the design team based on the phase of the design work in that semester. While students are not expected to become experts outside their discipline, multidisciplinary design work requires ALL students to contribute within and outside of their own areas of expertise, and often requires learning new skills outside of traditional disciplinary boundaries.

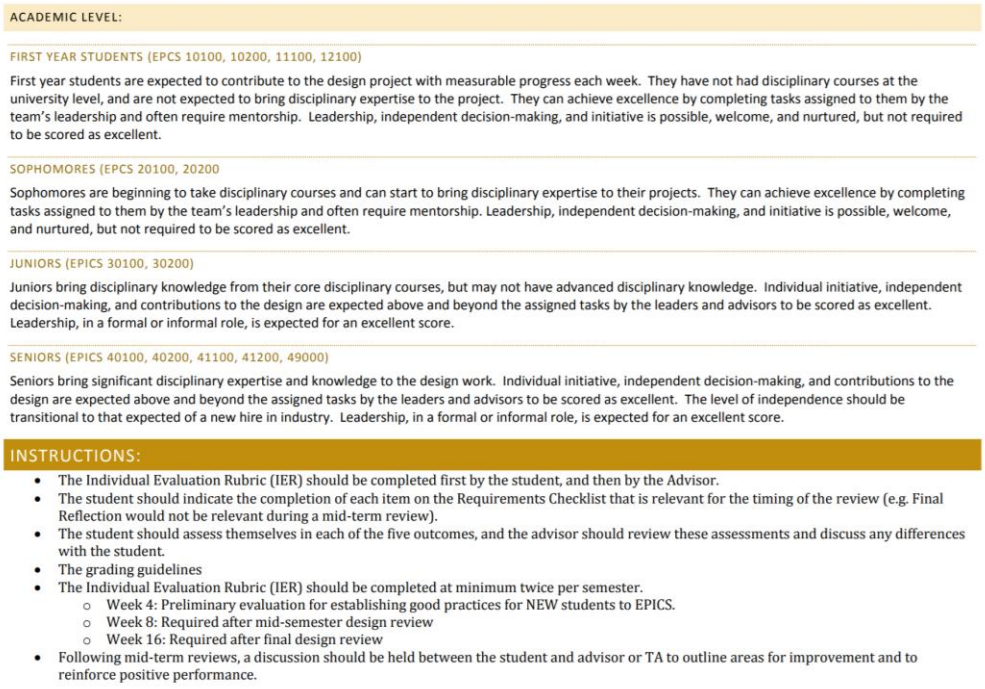
NUMBER OF SEMESTERS IN EPICS

Students in their first semester of EPICS may have a slower start as they acclimate to the EPICS environment. There are not lower standards, but in the formative evaluation there may be behaviors or documentation practices that need to be corrected. A new student may be able to improve their final grade more than a returning student from mid-term to the final assessment. A more experienced student would not have such a transition period, and is expected to work at a high level from the beginning of the semester.

NUMBER OF CREDIT HOURS

The minimum expectation for average hours worked outside of the formal lab session each week is 3.5 hours for one-credit and 5 hours for two-credit hour students. This difference in workload is the biggest difference between expectations for a one- vs. two-credit student. Two-credit students should be able to show evidence of accomplishments and work activities beyond their one-credit colleagues. Additionally, one-credit hour students must complete five Professional Development Hours (PDHs) and two-credit students must achieve ten PDHs.

Figure A-1: First page of IER Instructions



ACADEMIC LEVEL:

FIRST YEAR STUDENTS (EPCS 10100, 10200, 11100, 12100)

First year students are expected to contribute to the design project with measurable progress each week. They have not had disciplinary courses at the university level, and are not expected to bring disciplinary expertise to the project. They can achieve excellence by completing tasks assigned to them by the team's leadership and often require mentorship. Leadership, independent decision-making, and initiative is possible, welcome, and nurtured, but not required to be scored as excellent.

SOPHOMORES (EPCS 20100, 20200

Sophomores are beginning to take disciplinary courses and can start to bring disciplinary expertise to their projects. They can achieve excellence by completing tasks assigned to them by the team's leadership and often require mentorship. Leadership, independent decision-making, and initiative is possible, welcome, and nurtured, but not required to be scored as excellent.

JUNIORS (EPICS 30100, 30200)

Juniors bring disciplinary knowledge from their core disciplinary courses, but may not have advanced disciplinary knowledge. Individual initiative, independent decision-making, and contributions to the design are expected above and beyond the assigned tasks by the leaders and advisors to be scored as excellent. Leadership, in a formal or informal role, is expected for an excellent score.

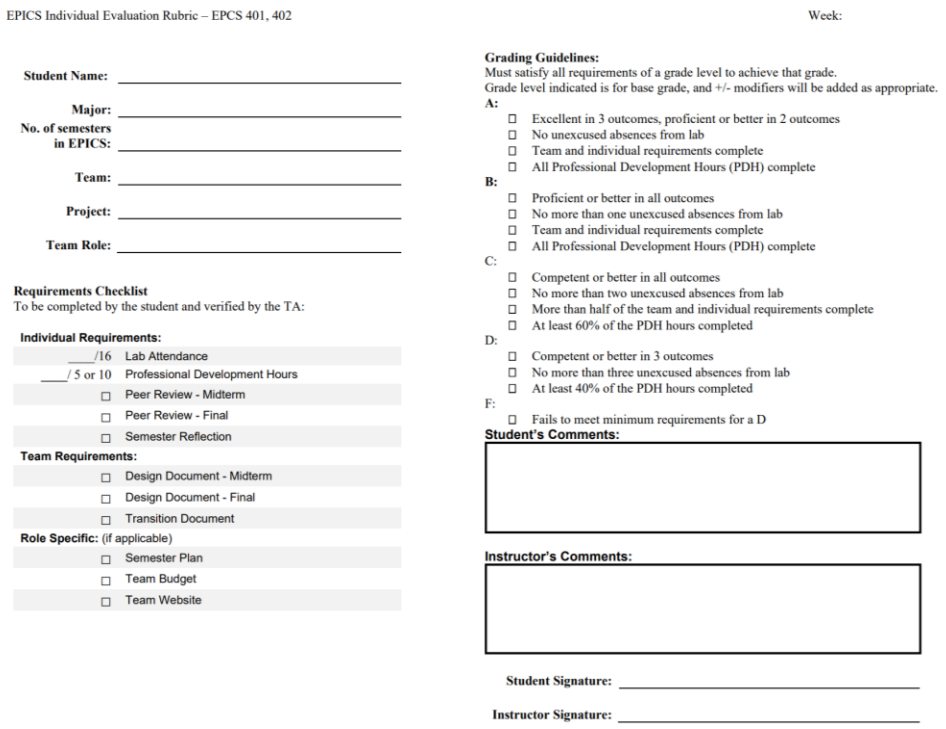
SENIORS (EPICS 40100, 40200, 41100, 41200, 49000)

Seniors bring significant disciplinary expertise and knowledge to the design work. Individual initiative, independent decision-making, and contributions to the design are expected above and beyond the assigned tasks by the leaders and advisors to be scored as excellent. The level of independence should be transitional to that expected of a new hire in industry. Leadership, in a formal or informal role, is expected for an excellent score.

INSTRUCTIONS:

- The Individual Evaluation Rubric (IER) should be completed first by the student, and then by the Advisor.
- The student should indicate the completion of each item on the Requirements Checklist that is relevant for the timing of the review (e.g. Final Reflection would not be relevant during a mid-term review).
- The student should assess themselves in each of the five outcomes, and the advisor should review these assessments and discuss any differences with the student.
- The grading guidelines
- The Individual Evaluation Rubric (IER) should be completed at minimum twice per semester.
    - Week 4: Preliminary evaluation for establishing good practices for NEW students to EPICS.
    - Week 8: Required after mid-semester design review
    - Week 16: Required after final design review
- Following mid-term reviews, a discussion should be held between the student and advisor or TA to outline areas for improvement and to reinforce positive performance.

Figure A-2: Second page of IER Instructions



EPICS Individual Evaluation Rubric – EPCS 401, 402

Week:

Student Name: _____

Major: _____

No. of semesters in EPICS: _____

Team: _____

Project: _____

Team Role: _____

Requirements Checklist
To be completed by the student and verified by the TA:

Individual Requirements:

___/16 Lab Attendance
___/ 5 or 10 Professional Development Hours
☐ Peer Review - Midterm
☐ Peer Review - Final
☐ Semester Reflection

Team Requirements:

☐ Design Document - Midterm
☐ Design Document - Final
☐ Transition Document

Role Specific: (if applicable)

☐ Semester Plan
☐ Team Budget
☐ Team Website

Grading Guidelines:
Must satisfy all requirements of a grade level to achieve that grade.
Grade level indicated is for base grade, and +/- modifiers will be added as appropriate.

A:
☐ Excellent in 3 outcomes, proficient or better in 2 outcomes
☐ No unexcused absences from lab
☐ Team and individual requirements complete
☐ All Professional Development Hours (PDH) complete

B:
☐ Proficient or better in all outcomes
☐ No more than one unexcused absences from lab
☐ Team and individual requirements complete
☐ All Professional Development Hours (PDH) complete

C:
☐ Competent or better in all outcomes
☐ No more than two unexcused absences from lab
☐ More than half of the team and individual requirements complete
☐ At least 60% of the PDH hours completed

D:
☐ Competent or better in 3 outcomes
☐ No more than three unexcused absences from lab
☐ At least 40% of the PDH hours completed

F:
☐ Fails to meet minimum requirements for a D

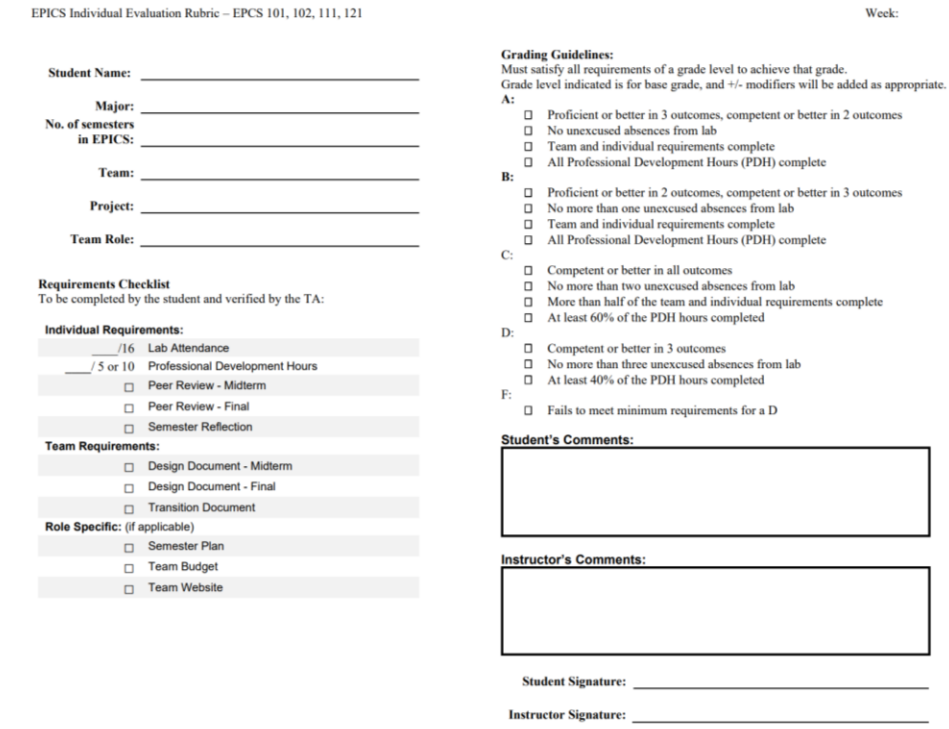
Student's Comments:

Instructor's Comments:

Student Signature: _____

Instructor Signature: _____

Figure A-3: Grading guidelines for 4th year students



EPICS Individual Evaluation Rubric – EPCS 101, 102, 111, 121

Week:

Student Name: _____

Major: _____

No. of semesters in EPICS: _____

Team: _____

Project: _____

Team Role: _____

Requirements Checklist
To be completed by the student and verified by the TA:

Individual Requirements:

___/16 Lab Attendance
___/ 5 or 10 Professional Development Hours
☐ Peer Review - Midterm
☐ Peer Review - Final
☐ Semester Reflection

Team Requirements:

☐ Design Document - Midterm
☐ Design Document - Final
☐ Transition Document

Role Specific: (if applicable)

☐ Semester Plan
☐ Team Budget
☐ Team Website

Grading Guidelines:
Must satisfy all requirements of a grade level to achieve that grade.
Grade level indicated is for base grade, and +/- modifiers will be added as appropriate.

A:
☐ Proficient or better in 3 outcomes, competent or better in 2 outcomes
☐ No unexcused absences from lab
☐ Team and individual requirements complete
☐ All Professional Development Hours (PDH) complete

B:
☐ Proficient or better in 2 outcomes, competent or better in 3 outcomes
☐ No more than one unexcused absences from lab
☐ Team and individual requirements complete
☐ All Professional Development Hours (PDH) complete

C:
☐ Competent or better in all outcomes
☐ No more than two unexcused absences from lab
☐ More than half of the team and individual requirements complete
☐ At least 60% of the PDH hours completed

D:
☐ Competent or better in 3 outcomes
☐ No more than three unexcused absences from lab
☐ At least 40% of the PDH hours completed

F:
☐ Fails to meet minimum requirements for a D

Student's Comments:

Instructor's Comments:

Student Signature: _____

Instructor Signature: _____

Figure A-4: Grading guidelines for 1st year students

EPICS Individual Evaluation Rubric – EPCS 401, 402 Week:

Outcomes	Excellent (E)	Proficient (P)	Competent (C)	Does Not (N) Meet Expectations	Assessment
Accomplishing Project Goals: Primarily evaluated from project deliverables and 'work and accomplishments' section of the notebook.	Documented individual disciplinary contributions to the project are **outstanding**, adding significant value to the team, partnership and design.	Documented individual disciplinary contributions to the project are **good,** adding value to the team, partnership and design.	Documented individual disciplinary contributions to the project are **adequate,** adding value to the team, partnership or design	Documented individual disciplinary contributions to the project are **inadequate.** without significant value to the team, partnership or design	Self-Assessment: Instructor's Assessment:
Justification for Self-Assessment: List up to three of your personal accomplishments and provide one sentence on where evidence can be found to demonstrate each (e.g. notebook section/date).					
Utilizing a Design Process: Primarily evaluated through Design Document and 'work and accomplishments' section of the notebook.	Demonstrates **comprehensive** understanding of the design process; implements process in the team design work and contributes in a significant way to the design document.	Demonstrates **good** understanding of the design process, with some evidence of putting process into practice and tangible contributions to the design document.	Demonstrates **adequate** understanding of the design process, implementing some elements into their own design work and contributing in some way to the design documents.	Demonstrates **lack of** understanding of the design process with no significant evidence of putting into practice or contributing to the design document.	Self-Assessment: Instructor's Assessment:
Justification for Self-Assessment: List up to three examples of process thinking (e.g. specification lists, brainstorming, decision matrixes, risk assessment, etc) and provide one sentence on where evidence can be found to demonstrate each (e.g. notebook section/date).					
Reflective/ Critical Thinking:** Primarily evaluated through reflections section of the notebook.	**Outstanding** critical and reflective thinking, including all three content components consistently well developed. Covers appropriate distribution of all themes over the semester.	**Building** critical and reflective thinking, including two content components generally well developed. Covers a variety of themes over the semester.	**Emerging** critical and reflective thinking, including one content component generally well developed.	**Inadequate** or missing critical and reflective thinking.	Self-Assessment: Instructor's Assessment:
Justification for Self-Assessment: List specific reflection themes (Social Impact, Ethics, etc.) and indicate primary examples of reflections on these themes.					

Figure A-5: Individual Evaluation Rubric – Page 1

EPICS Individual Evaluation Rubric – EPCS 401, 402 Week:

Teamwork/ Leadership: Primarily evaluated through team observation, 'meetings' section of notebook, and peer reviews.	**Outstanding** participation in class and team work, develops professional relationships, and fulfills role-specific responsibilities. **Excels** in work with team members, within and outside of formal team roles to accomplish team goals and leads when appropriate. Promotes team unity, assists others. **Outstanding** contribution to peer reviews.	**Good** teamwork and participation in class as well as role-specific responsibilities. **Willing** to work with other team members, within and outside of formal team roles, to accomplish team goals, Acquires new knowledge when prompted by others. **Good** contribution to peer reviews.	Participates in class and teamwork **when prompted**, including role-specific responsibilities. Shows **some willingness** to work with other team members, within and outside of formal team roles, to accomplish team goals, Acquires new knowledge when prompted by others. **Adequate** contribution to peer reviews.	**Inadequate** participation in class and teamwork, little or nothing done to build team unity. Incomplete role-specific responsibilities. **Little willingness** to work with other team members, within and outside of formal team roles, to accomplish team goals. **Inadequate** contribution to peer reviews.	Self-Assessment: Instructor's Assessment:
Justification for Self-Assessment: Provide up to three sentences describing your interactions with team members and performance in your team role.					
Communication: Primarily evaluated through written and verbal, formal and informal communication in team observation, design reviews, Design Document, and peer reviews.	**Outstanding** communication with all audiences. Completes all documentation needed for the team, design, project management, and transition with minimal need for editing.	**Good** communication with all audiences. Completes all documentation needed for the team, design, project management, and transition with some need for editing.	**Adequate** communication with all audiences. Completes most documentation needed for the team, design, project management, and transition with need for editing.	**Inadequate** communication both written and orally, formally or informally, to most audiences. Incomplete documentation needed for the team, design, project management, and transition.	Self-Assessment: Instructor's Assessment:
Justification for Self-Assessment: Provide up three sentences describing your written and verbal, formal and informal communications with team members, community partners, design reviewers, and the public.					

*Attach as addendum if needed.
** See https://www.aacu.org/value/rubrics/critical-thinking for definition of critical thinking.

Justification for two-credit hour students:

For two-credit students only, provide a brief description of the quantity and quality of work performed above and beyond the expectations for a one-credit student.

Figure A-6: Individual Evaluation Rubric – Page 2

Appendix B Reflection Examples

Sample Reflection #2

This week, we believed we had finished our FMEA. However, thanks to the documents our advisor sent us regarding FMEAs, I realized that we still had a few elements missing from it. Even if we had included a lot of information, we were still missing the severity, occurrence, and detection rankings. I have learned that when working on a long-term project such as this one, it is important to not just assume something is finished, such as this FMEA, a Gantt chart, or a design document. This is because in projects, things are constantly changing and progress is always being done, so the direction of the project might change, or new ideas might come up. When this happens, it is important to go back to documents such as these and update them, because documents regarding the project such as these are not truly completed until the project itself is finished, which is why it is important to always keep them in the back of your mind. Failing to update any of these documents can be detrimental because it might make you forget certain progress you have made, and it can also be harder to present your project to others because these documents are incomplete which makes it harder for others to understand what is going on. This is important to keep in mind when I work on projects in my career, because organization is essential in order to progress more effectively.

Sample #2 Feedback:

Includes all three content components. Area for possible improvement: specify which reflection theme this reflection is connecting to and slightly more specific thoughts on how to apply learning and experience in the future (example of a career item to keep organized, etc.).

Sample Reflection #5

This week I got to meet the new project partner and see the work site. I am very excited to be involved on a project like this and help an organization like [X]. I learned about ethics this week too, seeing an example of a project requirement from the project partner and an idea from a group member that didn't exactly match up. What I observed was that it is more important to complete the task the project partner wants than to add features that could be cool or fun to design.

Sample #5 Feedback:

Includes the first content component and some of the second. Attempts to connect to a reflection theme. Areas for possible improvement: consider referencing an engineering code of ethics to build discussion of theme around and include content component three.

Sample Reflection #7

This week we began to work with the team on creating a Gantt chart that outlined the timeline for the semester and also we split the work in two subsystem, three people were assign for the material part and there people were electrical part. I was assign to work with electrical design there for, I was started searching what I need for my subsystem in order to improve the electrical design.

Sample #7 Feedback:

Includes only the first connect component and connection to reflection theme is not clear. Reads more like a short journal entry. Recommend reviewing weekly reflection requirements - looking for all three content components well developed and clear connection to reflection theme(s).

Appendix C Senior Design Forms

Purdue University EPICS Senior Design Semester Report

Course Number and Title	
Semester/Year	
Advisor(s)	
EPICS Team	
Project Title	

Senior Design Students:

Name	Major	Area of Expertise	Expected Grad Date	On team 1st sem. of senior design?	On team 2nd sem. of senior design?

Other Team Members:

(Names of all project team members of the project team that have participated during the two semesters of the senior design students' experience on the team.)

Name	Major	Area of Expertise	Expected Grad Date	On team 1st sem. of senior design?	On team 2nd sem. of senior design?

Project Description: Provide a brief technical description of the design project, as outlined below.

(a) Provide a general description of the **product** (any device, system, process, software, etc. resulting from this design experience) to be delivered by this design project.

(b) What is the purpose of this **product**? For whom is it intended?

(c) Describe how the **engineering design process** used to create your product was utilized in this project. Include how you were able to develop and conduct appropriate experiments, analyze and interpret data, and use **engineering judgment** to draw conclusions related to the development of your product. (Note – Fundamental steps of the design process include: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation. However, more involved/detailed design processes can also be employed.)

(d) Describe the **design constraints**, and resulting **specifications**, incorporated into your product (list a minimum of 3).

(e) Describe how each of the following factors influenced your design **specifications** and **constraints**. (See definitions on first page)

- Public health, safety, and welfare
- Global factors

- Cultural factors
- Social factors
- Environmental factors
- Economic Factors

(f) Describe the appropriate **engineering standards** (see definition on first page) incorporated into the creation of your product.

(g) Describe the **final status** of your product.

(h) Describe the makeup of your project team and how you were organized to establish goals, plan tasks, and meet the objectives of this project.

(i) Did your project require the production of any written documentation other than this document (i.e., manuals, educational materials, etc.)? If so, describe the types, composition, and nature of the audiences (see definition on first page) for whom these materials were intended.

(j) Describe the types, composition, and nature of the audiences in attendance for the final oral design review. Discuss how you prepared for this audience.

EPICS Senior Design Outcomes Matrix

Student's Name: **Semesters Recorded:**

Team: **Project:**

Outcomes:	Describe how the student's realization of the outcome is documented	Student Initials & Date:	TA Initials & Date:	Advisor Initials & Date:
i. An ability to apply engineering design to create a product (any device, system, process, software, etc. resulting from this design experience) that meets the specified needs of this engineering design experience with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.				
ii. An ability to develop and conduct experimentation, analyze and interpret data, and use engineering judgment to draw conclusions related to the development of the product of this engineering design experience.				
iii. An ability to identify, formulate, and solve complex engineering problems arising from this engineering design experience by applying principles of engineering, science, and mathematics.				
iv. 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 associated with this design experience.				
v. An ability to communicate effectively with a range of audiences appropriate to this design experience in both a written report and oral presentation.				
vi. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies to complete the				

engineering design experience associated with this course.				
vii. An ability to recognize ethical and professional responsibilities associated with this engineering design experience and make informed judgments which must consider the impact of the product of this engineering design experience, in global, economic, environmental, and societal contexts.				