Focus Study of Collaborative Online International Learning (COIL) Engineering Projects

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1. Introduction

Engineers, and engineering educators, must continue to innovate in an increasingly global environment. As a result of the pandemic, engineering curriculum has grown to include effective working methods across global communities rather than only including the fundamental technical skills. The pandemic nurtured online methods for collaboration on global learning, which is "a process that prepares students for active global citizenship by involving them in collaborative global problem-solving as a central part of the college experience" (Vasquez et al., 2022). In the book, *Making Global Learning Universal*, the authors offer a deeper understanding of what global learning is and how to effectively lead a global project on a large scale. They offer professional development strategies in the context of student coursework and co-curricular activities. This book offers a framework for universities to engage students in global learning projects through actual experience and student participation (Landorf et al., 2018). The foremost example of these projects is Collaborative Online International Learning, or COIL. Collaborative Online International Learning incorporates meaningful and significant global experiences into student programs without physical, international travel. The COIL pedagogy was pioneered by The State University of New York (SUNY) and has been a leader in like programs since its conception over fifteen years ago. COIL is meant to be one aspect of the program that can elevate the impact of student learning. COIL programs can connect groups of students from different regions, time zones, and linguistic backgrounds (*What is COIL,* 2023). COIL can be implemented successfully in any discipline as it is focused on student teamwork, cross-cultural interactions, and learning at its core (*What is COIL,* 2023). Regardless of the socioeconomic status of a student, participation in a COIL course can be as formative as a study abroad experience when they may not be able to afford the former option. Through online interactions with global peers via a virtual project, intercultural awareness can be developed as well as more effective communication and collaboration skills. Research suggests that these experiences can guide students toward further global engagement and both professional and personal development later in their careers (Vahed et al., 2020). The pandemic has led to a rise in digital learning tools and online teaching capabilities, but it has created challenges for connection among peers. At its core, education is human interaction. To create an environment in which students can successfully learn remotely there needs to be a method for meaningful two-way interaction (*Remote learning during COVID-19,* 2023). In previous research, COIL teams have produced higher caliber work than teams that are not collaborating globally. In addition, COIL projects offer the opportunity for experiential learning, which is valued by employers and harder to come by in a traditional classroom environment (Appiah-Kubi et al., 2020). A COIL program

can take anywhere from five weeks to a whole class period, but the minimum recommended length is five weeks to solicit successful cross-cultural interaction. Additionally, an effective COIL module consists of four significant and distinct phases. As shown in Figure 1, a COIL program is organized into four phases that can take anywhere from five weeks to the entire length of the semester.

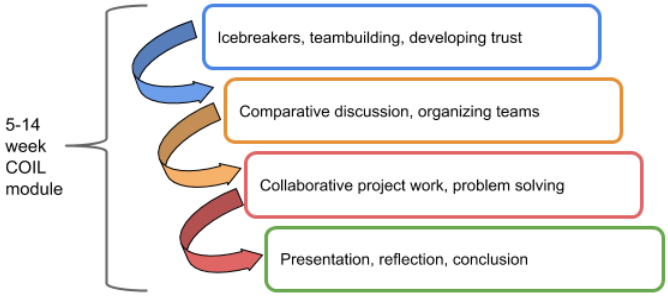

Figure 1. COIL Progression: Intro 2 COIL » What is COIL? (suny.edu)

The first phase involves the formation of teams and activities to introduce themselves to each other and begin to break the ice online. The second phase facilitates conversations from both groups of students about what each team will work on within the project scope. The third phase is the most weighted of the four as it focuses on addressing the main problem presented. Finally, the presentation phase was the shortest in duration as it would be accomplished all within the final week of the project timeline. For our COIL project, the duration was 6 weeks. This satisfies the minimum five-week recommendation by SUNY.

In this COIL program, students from University of Illinois Grainger College of Engineering collaborated with students from Zhejiang University to complete the entire project remotely through Zoom. The partnership between University of Illinois Grainger College of Engineering and Zhejiang University began in Fall of 2021 and provides Zhejiang University students the opportunity to complete a double degree with University of Illinois Grainger College of Engineering as well as their home university. This partnership is known as the Zhejiang University-University of Illinois Institute, or ZJUI. The program has grown since 2016 to include four engineering disciplines, electrical engineering, computer engineering, civil engineering, and mechanical engineering. Students join this cooperatively run program as freshman and complete coursework in, China prior to coming to University of Illinois at Urbana-Champaign for their junior year to complete either a semester or year on campus. Upon graduation, students have the potential to earn a bachelor's degree from both universities, if they have achieved sufficient credit for graduation of one or both programs. This project also allows for both sets of students to have access to global experience at scale (~400 total participants) in their first semester of university, which is an uncommon accomplishment. The goals of this COIL project is to give first year students the opportunity to work on an international project

together as a team and begin to understand the value of having different perspectives to solving problems.

On average, 40% of incoming University of Illinois Grainger College of Engineering first year students indicate on their new student summer registration homework that they are interested in study abroad. Due to COVID, study abroad programs were suspended or altered during 2019-2021 academic years. In the 2018-2019 Annual Report on Education Abroad at University of Illinois at Urbana-Champaign, the top five majors participating in study abroad are Accountancy, Finance, Business Administration, Advertising, and Psychology. While University of Illinois at Urbana- Champaign students have a dedicated study abroad office that offers support and access to both long- and short-term programs through the International Programs in Engineering (IPENG) office, they continue to study abroad at a lower rate than their peers in other colleges do. The common barriers and frequently asked questions for engineering students who wish to study abroad are the financial costs, coursework requirements, the effect on their overall timeline at the university, as well as other barriers.

For all the University of Illinois at Urbana-Champaign's study abroad participants, 12% of students participated in virtual experiences in 37 distinct programs. In the 2019-2020 school year, the average study abroad participant was a white female student in their junior year. The percentage of female engineering students at the University of Illinois at Urbana-Champaign has remained in the 18-25% range since the 2015 freshman class. While this value grows each year, it is important to note that while being an underrepresented minority within the college, they remain the majority of students who study abroad. Additionally, in 2019-2020, 13% of students who studied abroad were Hispanic, 7% Black, 4% multiracial, and 16% first-generation college students. There remains a lot of opportunity for diversification of the students participating in study abroad programs and for a larger network of University of Illinois at Urbana-Champaign students with a global experience.

COIL is not meant to be a substitute for traditional study abroad programs, but it stands to offer many new opportunities for students who otherwise would not participate in study abroad programs to engage in a global experience. By utilizing COIL project courses, University of Illinois at Urbana-Champaign can expand its global program offerings to include courses that do not require students to physically be in the country they are studying with or even leave campus to have a global interaction working with student from around the world.

2. Methods

2.1 Participant Selection and Background

For this study, University of Illinois Grainger College of Engineering (Grainger) and Zhejiang University (ZJUI) collaborated to provide a COIL project for first year students in engineering. Grainger students who were chosen to participate in the COIL program were Civil and Environmental Engineering and Engineering Undeclared students enrolled in Engineering 100. Engineering 100 (ENG 100) is a compulsory course for all freshmen at the University of Illinois at Urbana-Champaign which provides entering undergraduate students with opportunities to explore what it takes to be successful, both now as a student and in the future as an engineering professional. The course is facilitated by Engineering Learning Assistants, or ELAs, who are junior and senior students from within Grainger. Students apply and are trained for the ELA position. ENG 100 is divided into individual sections by major; each section has 20-25 students, and 10 to 12 sections participated each fall, for a total of 200-250 students.

The ZJUI version of ENG 100 is a mandatory project-based course with two projects. All students are enrolled in one section and meet with a total enrollment of 225 students across all engineering majors. This COIL project replaced the first ZJUI ENG 100 regular project. There were total of approximately 400- 450 student that participated each year in total.

The primary goals of choosing ENG 100 for a COIL project included: exposing first-year students to collaborating virtually and in international setting and providing an opportunity for first-year ZJUI students to interact with their Grainger based peers in hopes of cultivating connections and relationships for their future semester at University of Illinois at Urbana-Champaign. Per our joint agreement, ZJUI students must spend one semester on the University of Illinois at Urbana-Champaign campus during their junior year. Other than this project, the main source of connection that ZJUI students have with University of Illinois at Urbana-Champaign is through Grainger faculty. In addition, ENG 100 already utilized a Human Centered Design project that was easily adapted to the COIL framework.

Faculty at both ZJUI and Grainger developed the project topics each year for the COIL. Support for COIL at this large scale required additional staff on the ZJUI side. It also required new training for the course facilitators on the Grainger side. ZJUI had 13 facilitators and Grainger had 14-18 student course facilitators depending on section size. The ZJUI facilitators were a combination of faculty, graduate students, and postdocs, and the Grainger facilitators, as previously stated, were student course facilitators (ELAs). The grading rubric for the group project was based on previous HCD projects implementation at University of Illinois at Urbana-Champaign, using the following set of criteria: context, identified need, iterative process, reflection on feedback, solution, next steps, and presentation organization and skills. The

complete rubric is included in the Appendix A. For the second round of the project, a group peer evaluation was also developed based on feedback from the year before those students felt there was an unequal distribution of work in some teams.

The project runs from mid-October through mid-November for a total of six weeks. These dates were chosen because they fall between Chinese National Day and Fall Break for the students at University of Illinois at Urbana-Champaign. Project topics for year one and two are in Appendix B. Team formation was balanced around 2-3 Grainger students and 3-4 students from ZJUI per group based on the average class sizes. Both sides had presented their students with project topics and had the opportunity to discuss and rank the topics that interested them one through four. Administrators on both sides worked together to form teams based on interest.

2.2 Procedure

A COIL Project between selected sections of Engineering 100 in Grainger and the entire ENG 100 at ZJUI was developed to provide an opportunity for an online international learning experience. This project implemented in Fall of 2021 and 2022. University of Illinois at Urbana-Champaign has been a member of SUNY COIL's partner network since the summer of 2020 and utilized its tools and resources to implement this course.

The type of self-report assessments used in this COIL project to evaluate student learning outcomes and cultural competencies are frequently used in educational research and assessment, particularly in the context of co-curricular student activities such as service learning or study abroad (Davis et al., 2023). A survey instrument was utilized to evaluate the pre- and post - student responses and measure the student learning experiences in the ENG 100 sections with COIL projects around cultural competency and campus learning outcomes. Cultural competency is important for engineers so that they can work and relate effectively with people who are different from them, in terms of race, gender, and background (Bielefedt, 2008). Asking for self-assessment around the campus learning outcomes helps to understand the value of COIL projects as pedagogical method in achieving these learning outcomes. This survey instrument was developed in collaboration with the Center for Innovation, Teaching and Learning at the University of Illinois at Urbana-Champaign, which also assisted in administering the pre-and post-survey assessments. The Cultural Competency survey items were adapted from an American Society for Engineering Education paper, "Assessing Cultural Competence in Engineering Students" by Angela Bielefeldt of the University of Colorado at Boulder (Bielefeldt, 2008).

A univariate Analysis of Variance (ANOVA) was conducted to compare students' cultural competency pre-course knowledge based on course section. Then, a univariate ANOVA was conducted to compare students' cultural competency post-course knowledge based on

course section. Finally, a repeated measures ANOVA was conducted to check for the difference between pre- and post-course means by course section.

Students were asked to rate their level of agreement with a set of 12 statements with these instructions:

Please tell us how much you personally agree or disagree with the following statements. The possible answer categories are:

1. *Strongly agree*
2. *Moderately agree*
3. *Slightly agree*
4. *Neither agree nor disagree*
5. *Slightly disagree*
6. *Moderately disagree*
7. *Strongly disagree*

Higher scores on these items represent a higher level of cultural competence, so some of the items were reverse scored to accomplish this. (Reverse scoring means that "Strongly agree" is scored as a 7 instead of a 1, "Moderately agree" is scored as a 6 instead of a 2, etc. The respondents never see the scoring numbers in the questionnaire, only the verbal labels for each point.) The means and standard deviations presented in Table 1 (below) reflect this reverse scoring, as noted. In addition, we assessed the Cultural Competence (CC) scale for internal consistency (reliability) using Cronbach's alpha statistic. In so doing, we discovered that two of the items (7 and 10) detracted from the overall reliability of the scale, and so removed them from the calculation of the composite CC score. The resulting alpha reliability coefficient is .75 (for the Grainger students) which represents an acceptable level internal consistency.

The 12 Items

1. The technology that is used in the United States is likely the best technology to use to solve similar technical problems in other countries.
2. There is a single best solution to every engineering problem.
3. It is important for engineers to consider the broader potential impacts of technical solutions to problems on minority racial and ethnic groups in the affected population.
4. Technical constraints and criteria are the most important elements determining the success of an engineered solution.
5. Most engineers in the United States would define an engineering problem similarly to each other.
6. Engineers in the United States would define an engineering problem similarly to engineers in other countries such as India or China.
7. If two teams of engineers design different solutions to an engineering problem, stakeholders are likely to disagree on which solution is better.
8. The technology that is used on the United States mainland is not likely to be the best technology to use to solve similar technical problems in other countries such as India or China.

9. Engineers are able to design good solutions to engineering problems if given sufficient technical data, even without visiting the community or talking with stakeholders.
10. I would be equally comfortable teaming with an engineer from the United States as one in India or China.
11. Given a range of engineering designs to solve a particular problem, different stakeholder groups are likely to agree on which design is best.
12. I expect that a water treatment plant designed for a 100,000-person city in University of Illinois would also be a good solution for a 100,000-person city in China if the inlet water quality were similar.

The white paper scale developed by Bielefeldt was used in the first year (Fall 2020/Spring 2021), revised in the second year (original Scale in the third year as our second-year revision did not improve Fall 2021/Spring 2022), and then we returned to the original 12 items using the scale published by Angela Bielefeldt scale in the third year as our second year revision did not improve the scale in any way. The revision consisted of the original 12 items from the white paper which were measured on an agree-disagree scale. We re-wrote eight of these items to be on item specific scales. The items used in the survey during the Fall 2022 semester were "Agree-Disagree", "Importance", "Likelihood", and "Other". Their response categories ranged from five to seven point scales. See the full statements for the additional items and their scales as the scoring considerations in Appendix C.

2.3 Learning Outcomes Measures

Our learning outcomes measures are based on a set of outcomes endorsed by and employed on the University of Illinois at Urbana-Champaign campus for our courses. For reference, see: https://provost.illinois.edu/assessment/learning-outcomes-assessment/illinois-student-learning-outcomes . The five learning outcomes are:

1. Intellectual Reasoning and Knowledge (IRK): Acquisition of broad and deep knowledge across academic disciplines and fields. (8 survey items)
2. Creative Inquiry and Discovery (CID): Application of knowledge to promote inquiry, discover solutions, and generate new ideas and creative works. (3 items)
3. Effective Leadership and Community Engagement (ELCE): Building and sustaining productive relationships to respond to civic and social challenges at local, national, and global levels, creating positive change in their communities. (3 items)
4. Social Awareness and Cultural Understanding (SACU): Development of a critical and reflective orientation toward such social and cultural differences as race, indigeneity, gender, class, sexuality, language, and disability (4 items)
5. Global Consciousness (GC): Discovery of how complex, interdependent global systems—natural, environmental, social, cultural, economic, and political—affect and are affected by the local identities and ethical choices of individuals and institutions. (2 items)

For the learning outcomes measures, at the **end** of the course, we ask the students a set of 20 questions with these instructions:

> *Each college course you take may help you improve your abilities in a variety of areas. For example, some courses may improve your critical thinking skills; some may improve your communication skills; and some courses may not improve your abilities in any area at all. Please indicate how much your abilities have improved in the following areas AS A RESULT OF your enrollment in [Course Name]. We are interested only in the improvement that you attribute to this particular class: [Course Name].*
>
> *How much have you improved your abilities to do the following things as a result of [Course Name]?*

Then the 20 learning outcome items are presented with the following possible answer categories:

1. *Not at all*
2. *A little*
3. *A moderate amount*
4. *Very much*
5. *An extraordinary amount*

3. Results and Discussion

A repeated measures ANOVA was conducted to check for the difference between pre- and post-course means by course section. There were no statistically significant differences between pre- and post-course scores. There were no statistically significant differences in gains, scores, or normalized gain scores.

Table 1. Mean Cultural Competence Scores, ENG 100 Course by Sections at the two different universities.

Scale ranges from 1 to 7 with a higher score indicating a higher level of cultural competence.

Section	Term	Pre-course survey			Post-semester Survey		
		Mean	Std. Dev.	N	Mean	Std. Dev.	N
ENG 100: Engineering Orientation (University of Illinois)	Fall 2021*	4.54	.72	80	4.43	.90	71
	Fall 2022	3.52	.81	72	3.61	.81	43
ENG 100: Engineering Orientation (Zhejiang University)	Fall 2021*	4.24	.79	194	4.29	.82	147
	Fall 2022	3.77	.78	116	3.89	.83	189

* A slightly different Cultural Competence scale was used in Fall 2021 and Spring 2022

After calculating their index scores, a Z-score was made (score-mean of score divided by the standard deviation). All scores were then compared as standard deviations. The pre- and post-scores are then subtracted from each other on the terms.

Table 2. Mean Difference Between Pre-Course Cultural Competence Scores and Post-course Scores expressed in terms of Standard Deviations, ENG 100

Negative values indicate a decrease in cultural competence over time; positive values indicate an increase in cultural competence. A value of zero indicates no change.

Section	Term	Difference Between End-of-Semester Score and baseline	
		Mean difference in terms of SD	N who took both surveys
ENG 100: Engineering Orientation (University of Illinois)	Fall 2021*	-.21	34
	Fall 2022	.05	23
ENG 100: Engineering Orientation (Zhejiang University)	Fall 2021*	.06	137
	Fall 2022	.01	104

* A slightly different Cultural Competence scale was used in Fall 2021 and Spring 2022

Generally, 0.20 std dev change is considered a 'small' change, 0.50 represents a 'medium' change size and 0.80 a 'large' change (Cohen's d). In order to have large enough N's to do the significance testing on score differences, each course section was aggregated for all the semesters together.

Table 3. Mean Difference Between Pre-Course Cultural Competence Scores and Post-Course Scores expressed in terms of Standard Deviations, aggregated across two semesters

Negative values indicate a decrease in cultural competence over time; positive values indicate an increase in cultural competence. A value of zero indicates no change.

Section	Difference Between End-of-Semester Score and baseline	
	Mean difference in terms of SD	N who took both surveys
ENG 100: Engineering Orientation (University of Illinois)	-.10	57
ENG 100: Engineering Orientation (Zhejiang University)	.03	241

* A slightly different Cultural Competence scale was used in Fall 2021 and Spring 2022

Generally, 0.20 std dev change is considered a 'small' change, 0.50 represents a 'medium' change size and 0.80 a 'large' change (Cohen's d). There were no statistically significant differences between scores over time. (Paired samples t-test).

Table 4. Learning outcome item means for Engineering 100 section by semester

Learning Outcome Items (All items on 5-pt scale)	**ENG 100 (University of Illinois)**		**ENG 100 (Zhejiang University)**	
	Fall 2021	**Fall 2022**	**Fall 2021**	**Fall 2022**
Intellectual Reasoning and Knowledge (IRK)				
Think logically and critically	2.94	3.22	3.67	3.74
Identify credible sources of information	2.79	3.12	3.45	3.55
Solve problems using evidence	2.77	3.07	3.60	3.63
Communicate in writing	2.83	3.10	3.61	3.51
Communicate orally	3.13	3.34	3.52	3.64
Think in creative ways	3.03	3.12	3.65	3.78
Deeply understand your chosen field of study	3.14	3.34	3.63	3.72
Explore questions or problems from more than one disciplinary viewpoint	3.00	3.12	3.49	3.38
8-item Composite IRK score	2.95	3.18	3.58	3.62
Creative Inquiry and Discovery (CID)				
Analyze data, creative works, literature, or information to investigate problems	3.23	3.44	3.48	3.48
Ask compelling questions related to your area of interest or major	2.64	3.05	3.61	3.60
Convey new ideas	3.34	3.59	3.68	3.86
3-item Composite CID score	3.07	3.36	3.59	3.64
Effective Leadership and Community Engagement (ELCE)				
Collaborate with others effectively	3.36	3.63	3.72	3.93
Consider a variety of perspectives when making decisions as a group	3.30	3.60	3.75	3.88
Develop ways to give back to your community	2.93	3.29	3.41	3.54

3-item Composite ELCE score	3.20	3.51	3.63	3.78
Social Awareness and Cultural Understanding (SACU)				
Work in diverse teams	3.54	3.78	3.50	3.71
Participate in discussions about cultural differences with others	3.01	3.41	3.43	3.47
Explore multiple perspectives	3.30	3.66	3.75	3.79
Have a deeper understanding of different social and cultural groups	2.99	3.59	3.52	3.45
4-item Composite SACU score	3.21	3.61	3.55	3.60
Global Consciousness (GC)				
Identify factors that make a difference in how communities around the world operate	3.00	3.46	3.40	3.35
Appreciate how events in one location can have a global impact	2.83	3.38	3.34	3.36
2-item Composite SACU score	2.91	3.43	3.36	3.35
N	70	41	147	189

From the Table 4 means, it is important to note that in general, the ENG 100 (ZJUI) sections reported improving their abilities more than the Grainger sections such as in the following:

- Thinking logically and critically
- Identify credible resources
- Solve problems using evidence
- Communicate in writing
- Think in creative ways
- Explore questions using more than one disciplinary viewpoint
- Intellectual Reasoning & Knowledge (IRK) Composite Score
- Creative Inquiry & Discovery (CID) Composite Score
- Effective Leadership & Community Engagement (ELCE) Composite Score

However, there were some interesting improvements for the Grainger sections between 2021 and 2022. Grainger students improved their ability significantly in the learning outcomes "Analyze information" and "Collaborate with others effectively."

For the below learning outcomes, Grainger sections improved their abilities. At the same time, ZJUI did not improve between 2021 and 2022 but also did not show improvement overall between semesters. ZJUI sections did show improved ability however when comparing the two 2021 sections at both universities.

- Participate in discussions about cultural differences
- Explore multiple social and cultural perspectives

- Deeper understanding of different social and cultural groups
- Social Awareness and Cultural Understanding (SACU) Composite Score
- Identify factors that make a difference in how communities operate around the world
- Appreciate how events can have a global impact
- Global Consciousness (GC) Composite Scale

Specifically for the learning outcome, "Effective Leadership & Community Engagement (ELCE) Composite Score," Zhejiang University students improved their ability more than the University of Illinois at Urbana-Champaign sections in both semesters. In the 2021 semester, ZJUI sections indicated they improved their ability significantly more than the Grainger sections in the following learning outcomes "Communicate orally" and "Deeply Understand chosen field of study" though there was no difference between the 2022 sections and no difference by semester within each section. For the learning outcomes "Convey new ideas," "Consider a variety of perspectives," and "Develop ways to give back to your community," ZJUI improved their ability more than the Grainger sections in 2021, but no significant difference was identified by semester within each section. Finally, there were no significant differences between the two university sections regardless of semester when it came to the learning outcomes "Ask compelling questions" or "work in diverse teams."

4. Summary and Conclusions

COIL courses were first implemented in Fall of 2020. Through continued implementation and improvement of this survey tool, a stronger sample set can be constructed to better understand the impact that COIL projects in engineering courses have on student learning outcomes. The Cultural Competency Scores were likely higher in the pre-course survey than in the post-semester survey for both Grainger and ZJUI students because can have a tendency to overestimate their knowledge/ability on the pre-test and the self-correct or even underestimate their knowledge/ability after the experience. Through participation in the project over the semester, students gain awareness of the Cultural Competencies, and they are improving in meeting University of Illinois at Urbana-Champaign' campus learning outcomes. ZJUI students also had higher ratings for themselves in both the pre-course survey and the post-semester survey, which could be attributed to the prestige of their program. Zhejiang University is a predominately monolingual and mono-ethnic campus. Their perception of their Cultural Competency may be higher than Grainger students because of their admission into a prestigious program for high achieving students which involves cultural opportunities such as studying abroad at University of Illinois at Urbana-Champaign.

The results indicate significant improvement for ZJUI students over the course of a project length, while Grainger students improved their abilities significantly between the 2021

and 2022 sections. This is likely due to lessons learned from year one (2021), improvements made in training of the facilitators, and better overall project management in year two (2022).

Future work includes exploring the opportunity to translate the survey into Mandarin for ZJUI students to allow them to take it in their native language as well as exploring further the impact cultural acquiescence bias from ZJUI students and ways of improving survey results.

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Appendix A

Final Presentations Checklist

Criteria	1 - Approaching Expectations	3 - Meeting Expectations	5 - Exceeding Expectations
Context	Designers provide some context for the design solution they present. It somewhat addresses the human-centered angle and background information.	Designers clearly describe the context for the proposed solution including the human-centered angle and background information about the problem.	Designers thoroughly describe the context for the presentation. They provide a complex description of the problem, demonstrating they explored multiple angles to understand the context.
Identified Need	Designers generally describe the need for this proposed solution and/or allude to the context. It may only partially address the human-centered element, or may be an idea that was not developed from a different user's perspective.	Designers describe the need for this proposed solution and how it was created from someone else's perspective, building off the context and addressing the human-centered element.	Designers completely outline the identified need. Not only does it build off the context, but it describes the need from a variety of perspectives.
Iterative Process	Designers describe some elements of their iterative process fully. The description may include only partial explanations of their brainstorming, convergence toward viable solutions, and/or the testing process.	Designers describe the iterative process they went through to get to the solution(s) they are presenting. This process should include an overview of their brainstorming, convergence toward viable solutions, and the testing process.	Designers provide a detailed description of their iterative process from brainstorming to testing. Each step of the process includes specific examples to demonstrate how they got to their proposed solution.
Reflection on Feedback	Designers describe the feedback they received or how they responded to feedback to improve	Designers describe the feedback they received during the iterative process and how they	Designers thoroughly describe the feedback they received during the iterative process,

	their designs. They may describe both generally rather than in depth.	responded to that feedback to improve the proposed physical, digital, or experiential design.	including evidence that feedback came from a variety of stakeholders. They outline how each piece of feedback was addressed to improve the design.
Solution	Designers describe their solution and how it addresses the context, but may only make general connections between the context and the solution. Their description may only basically address the human-centered aspects.	Designers clearly describe their solution and how it addresses the context and identified need, including where applicable how the solution functions.	Designers fully describe the solution and how it addressed the context and identified need. The designers also highlight the trade-offs and affordances that this solution has.
Next Steps	Designers generally address their next steps. The description may include some discussion on whether there will be additional tests or a general plan for implementation.	Designers outline clear next steps in the design process such as expanding testing of the prototype with users or how they will implement the solution.	Designers provide a complete plan for next steps including specific tests they want to run, stakeholders they need to get feedback from, and plans for implementation.
Presentation Organization	Designers generally organize their presentation in a logical manner, but may lack a narrative style. The presentation uses visuals or other modes that are sometimes effective. Some aspects of the presentation narrative may be uneven or seem disjointed.	Designers organize their narrative presentation in a clear and logical manner. The presentation makes effective use of the presentation platform (e.g. Power Point, Prezi, etc.) integrates visuals (or other modes) as necessary to convey ideas clearly.	Designers organization of the narrative seamlessly flows throughout in a logical and creative manner. The visual presentation (and other modes) enhances the verbal/non-verbal communication.
Presentation Skills	Designers unevenly communicate their ideas to an audience. There	Designers effectively communicate ideas to an audience through their	Designers make connections with the audience through their

	may be a mismatch between verbal and non-verbal communication.	verbal and non-verbal communications. This includes effective voice control, eye contact, and gestures.	effective use of verbal and non-verbal presentation skills.
TOTAL			**/40**

Appendix B

Human Centered Design Project Topics from Fall 2021

- Online Communication
- Learning Management Systems
- Transportation on Campus
- Sustainability in Cafeterias and Dining Halls

Human Centered Design Project Topics from Fall 2022

- Reduce energy consumption in buildings
- Reduce energy consumption in transportation
- Improving access to environmental education
- Improving access to green spaces within communities

Appendix C

Full descriptions of the items used in the survey during the Fall 2022 semester, their response categories, and scoring considerations.

Agree-disagree items

We asked students to rate their level of agreement with 4 statements with these instructions:

> *Please tell us how much you personally agree or disagree with the following statements.*

The 4 agree-disagree statements are:

> *1. There is a single best solution to every engineering problem.*
> *2. Most engineers in the United States would define an engineering problem similarly to each other.*
> *3. Engineers in the United States would define an engineering problem similarly to engineers in other countries.*
> *4. The technology that is used in {home country} is likely to be the best technology to use to solve similar technical problems in other countries.*

The possible answer categories are:

1. *Strongly agree*
2. *Moderately agree*
3. *Slightly agree*
4. *Neither agree nor disagree*
5. *Slightly disagree*
6. *Moderately disagree*
7. *Strongly disagree*

Importance items

We asked students to rate importance on 3 items:

5. How important are technical constraints and criteria in determining the success of an engineered solution?
6. How important is it for engineers to consider the broader potential impacts of engineering solutions on minority groups (racial, ethnic, religious, etc.) in the population?
7. How important is it for engineers to visit the local people and stakeholders in designing a good solution to an engineering problem for a community?

The possible answer categories are:

1.0 Not important at all
2.5 Slightly important
4.0 Moderately important
5.5 Very important
7.0 Extremely important

Likelihood items

We asked students to rate likelihood on 2 items:

8. If given a range of engineering designs to solve a particular problem, how likely are different stakeholder groups to agree on which design is best?
9. How likely is it that a water treatment plant designed for a 100,000-person city in {home country} would also be a good solution for a 100,000-person city in another country if the inlet water quality were similar?

The possible answer categories are:

7.0 There is no chance (they would agree/it would be a good solution)
5.5 There's a 25% chance (they would agree/it would be a good solution)
4.0 There's a 50% chance (they would agree/it would be a good solution)
2.5 There's a 75% chance (they would agree/it would be a good solution)
1.0 There's a 100% chance (they would agree/it would be a good solution)

Other items

We asked students 3 other items with their own unique response categories:

10. How well would the engineering technology that is used in {home country} work to solve similar problems in other countries?

*T*he possible answer categories are:

7.0 Not well at all
5.5 Slightly well
4.0 Moderately well
2.5 Very well
1.0 Extremely well

11. How easy or difficult do you think it would be to deal with the cultural aspects of collaborating with engineering colleagues from other countries?

The possible answer categories are:

1. *Very difficult*
2. *Moderately difficult*
3. *Slightly difficult*
4. *Neither easy nor difficult*
5. *Slightly easy*
6. *Moderately easy*
7. *Very easy*

12. How comfortable would you feel in teaming up with an engineer from another country to design a solution to an engineering problem?

The possible answer categories are:

1.0 Not comfortable at all
2.5 Slightly comfortable
4.0 Moderately comfortable
5.5 Very comfortable
7.0 Extremely comfortable

Scoring considerations

Each item is scored so that a higher value indicates a higher level of cultural competence. The 5-point items were scored on an equidistant scale from one to seven so that they could be combined easily with the 7-point items. In addition, we assessed the CC scale for internal consistency (reliability) using Cronbach's alpha statistic and the resulting coefficient is .72 (for the University of Illinois students) which represents an acceptable level of internal consistency.