Collaborative Research: Research Initiation: Assessing Global Engagement Interventions to Advance Global Engineering Competence for Engineering Formation

1. Introduction

This paper summarizes the work performed during the first year of a collaborative Research Initiation in Engineering Formation (RIEF) project focused on assessing the formation of a global learner mindset in engineering students through the use of different types of global engagement interventions without extended international travel. During this year the global engagement interventions have been developed, piloted, and assessed using the Global Engagement Survey (GES) and Global Engineering Competency Scale (GECS) instruments in a pre and post format. The assessment results helped the research team update the interventions and refine the assessment strategy, including the addition of new qualitative questions aimed at better understanding each interventions' impact on developing the students' global engineering skillset.

2. Background and Motivation

In response to a need to develop engineers that have a global learner mindset, four distinct global engagement interventions were developed: (i)the use of international engineering case studies in a quantitative analysis course,(ii) the intentional formation of multinational student design teams within a capstone design course, (iii) a Collaborative Online International Learning (COIL) research project in a transport phenomena course, and (iv) an engineering course coupled to a community-engaged project. The research aims to address the following questions:

1. To what extent can global competence be developed in engineering students through the use of the proposed global engagement interventions?
2. What are the relative strengths of each of the proposed global engagement interventions in developing global engineering competence?

For this project, the concept of global competence aligns with the University of Dayton's (UD) institutional definition of intercultural competence. According to UD, intercultural competence involves the process of listening, learning, and reflecting to develop knowledge, skills, attitudes, and commitments for engaging across diverse groups in open, effective, and socially responsible ways. The project adheres to the three student learning outcomes outlined in the UD International and Intercultural Leadership Certificate, focusing on students' ability to:

1. Explain how issues of social justice, power and privilege are shaped in a variety of contexts.
2. Use language and knowledge of other cultures effectively and appropriately to communicate, connect and build relationships with people in other cultural communities.
3. Express respect and thoughtful engagement with people across cultures.

These outcomes focus on the development of a global learner mindset which is foundational to developing a global engineering competence in students.

3. Global Engagement Interventions

The four global engagement interventions were developed and implemented during the spring 2023 semester as detailed below. All students in the four interventions took the surveys at the beginning (pre) and end (post) of the semester.

3.1. International Engineering Case Study in a Quantitative Analysis Course

Quantitative Analysis is an undergraduate Engineering Technology course that introduces students to the mathematical techniques used to support decision making and managerial analysis. This is a required course for Industrial Engineering Technology students that is typically taken in their junior or senior year. After the introduction of linear programming, students participated in an approximate 10 week case study that aimed to apply network modeling to a problem based on real-world events. Inspired by the historical seismic activity of the Middle East, the Spring 2023 class case study sought to develop a distribution plan of relief supplies (ex., bottled water) from pre-positioned storage facilities in Turkey that could be used in the event of a natural disaster. The case study involved 4 research assignments the students completed outside of class paired with 4 in-class discussion days where students shared what they learned and worked together to develop a network model.

The first assignment required students to read one of two assigned articles that discussed successful applications of humanitarian logistics. The second assignment required students to familiarize themselves with Turkey's geography, including the characteristics of each region, the location of key transportation hubs, the identification of major cities and their corresponding populations, and the seismic activity of those cities. At the first class discussion, students shared the information they learned from both assignments with each other and discussed key features and characteristics that should be considered when selecting the location for a pre-positioned storage facility for relief supplies. The third assignment asked students to consider the available modes of transporting goods through Turkey as well as the regional geographies and identify candidate locations for storage facilities. The fourth assignment asked students to find video or print news reports that discussed the humanitarian relief efforts that were made in Turkey in response to the February 2023 earthquake. The second and third class discussions allowed students the opportunity to discuss the pros and cons of all candidate locations and resulted in the selection of 6 locations for storage facilities. The solution procedure, based on content taught in previous class lectures, was also discussed and agreed upon. The last class discussion presented the optimal distribution plan of relief supplies from the selected facility locations to all major cities in Turkey. At the end of the semester, students were asked to submit reflections regarding the implementation of the case study as well as the lessons they learned as a result of participating in it.

3.2. Intentional Formation of Multinational Student Design Teams Within a Capstone Design Course

During the Spring 2023 semester, the Senior Capstone Course at UD School of Engineering introduced a specialized intervention to develop students' cultural competencies, essential for the globally interconnected engineering sector. Targeted at upper-level engineering students, this course emphasizes applying engineering principles in multidisciplinary team-based design projects. It covers the comprehensive product realization process, from idea generation to proposal development and decision analysis. A key aspect of the course is the integration of intercultural content, which is introduced during team formation and reinforced through various stages, including ideation, decision methodology, and writing. This integration aims to prepare students for the diverse and multicultural nature of the global engineering workforce.

In this intervention, team composition was carefully curated to include members from different ethnic and national backgrounds, enhancing students' skills in professional communication, task delegation, and interpersonal interactions within a multicultural context. The course was meticulously managed to ensure that this diverse team composition translated into significant learning experiences, rather than just superficial exposure to diversity. Modules emphasizing the practical application of intercultural content were included, encouraging students to engage in reflective practices and consider different perspectives. This approach was designed to improve students' team dynamics in the immediate term and equip them with essential collaboration skills for their future professional careers. Instructors tailored the intervention to each international pair group, ensuring a personalized and effective learning experience, adaptable to the unique dynamics and needs of each team.

3.3. COIL Research Project in a Transport Phenomena Course

During the Spring 2023 term, chemical engineering (CME) students at UD worked in a COIL experience to complete a four-week cross-cultural technical project with chemical engineering students in Colombia, (Universidad Nacional, Manizales). The Transport Phenomena II course at UD is a required course for junior students in the chemical engineering program. In Colombia, students must also take a Transport Phenomena Course (4100932-1: Fenomenos de Transporte). Teams of four students (2 UD + 2 UNacional) had to solve a Transport Phenomena problem using COMSOL™ multiphysics that the instructor had not solved or was not a traditional lecture example. The project was an open-ended assignment. Students defined the problem, posed a step-by-step solution, and compared the results to experimental data or analytical solutions. The problem could include combined heat/mass, fluid-flow/heat, and mass/fluid-flow problem statements.

Before the pre-surveys, the instructor introduced the benefits of participating in international experiences and a few concepts of intercultural competence. During the first week of the activity, students learned about each other's intercultural aspects by preparing a short introductory video with a biography and an identity element (favorite food, music, etc.). The technical activity took place during weeks 2 - 3. Instructors expected students to experience a gap in finding technical

information or discussing past experiences (e.g., co-ops) when defining the Transport Phenomena problem. Deliverables included a one-page technical memorandum and a video recording using a Pechakucha format style by the end of week 4. Due to different course enrollments at both institutions, only 11 groups (2 UD + 2 UNacional) fully participated in the COIL experience. At UD, five teams (17 students) did not have the opportunity to participate in the experience (COIL No international). Surveys (GEC and GECS) were provided to all the UD participants.

3.4. Engineering Course Coupled with a Community Engaged Project

Within the Ethos Center there is an Engineering Design and Appropriate Technology (ED&AT) course that includes a 10-day international breakout. This course was designed to introduce students to community engaged engineering and design principles within cultural contexts and to prepare them for a 10-day faculty led international community engaged engineering project. The course is three-credits and counts as a technical elective in most of the UD School of Engineering programs. The scope of the travel time was kept short to fit within the heavily constrained schedules of engineering students which often includes both coursework semesters and co-op and internship semesters. This course ran during the spring 2023 semester with the breakout travel component taking place in Alotenango, Guatemala during spring break.

Helping students develop a global learner mindset is a key outcome for the ED&AT course and therefore it is purposefully planned throughout all aspects of the course. The course topics include becoming a self-aware engineer and becoming a culturally aware engineer, specifically targeting the global learner categories of global citizenship, cultural humility, and critical reflection. Through the course the students examine their own ideological assumptions and how these beliefs impact their worldview. Finally, the students work through a design thinking approach that incorporates system thinking through the lenses of sustainability, social justice, and human rights. Throughout the course and breakout immersion, the students participate in reflective practices.

4. Data Analysis

The profile of the students in each of the interventions during the spring 2023 semester is shown in Table 1 along with the number of matched responses pre/post for the GES and pre/post for the GES and GECS together. Note that the COIL project was administered in a required course; however, the students self-selected to collaborate with students from an international university by participating on a COIL project team. Table 2 includes some demographic information on the participants.

Table 1: Populations for global engagement interventions

Global Engagement intervention	Required / Elective	Student Grade	Class Enrollment	Matched Responses	
				GES	GES w/ GECS
International case study Engineering Technology	Required	Soph., Jr., & Sr.	9	8	8
Multi-national student teams Computer, Electrical, and Mechanical Engineering	Required	Sr.	50	20	12
COIL project Chemical Engineering	Required	Jr. & Sr.	39	17	16
Engineering course with community engaged project All Engineering Students	Elective	Soph., Jr., & Sr.	18	14	11

Table 2: Demographics of global engagement intervention participants

	All students		Case Study		COIL		Campstone Teaming		International Breakout	
	N	%	N	%	N	%	N	%	N	%
Gender (men)	46	72%	5	63%	17	68%	16	94%	8	57%
Race (white)	48	75%	3	38%	23	92%	13	76%	9	64%
Nationality (USA)	59	92%	4	50%	25	100%	16	94%	14	100%

4.1. GES - Quantitative

Matched data from the pre and post GES assessments of the four global engagement interventions was analyzed. For each matched pair, the change in score from pre to post assessment for each of the GES scales was calculated. The score changes for each of the GES scales, openness to diversity (OD), cultural adaptability (CA), civic efficacy (CE), political voice (PV), conscious consumption (CC), global civic responsibility (GCR), human rights beliefs (HRB), critical reflection (CR),. The expected impact of each global engagement intervention according to the GES learning outcomes along with the overall student learning outcomes for the project is shown in Table 3. The cultural humility outcome consists of the OD and CA scales, and the global citizenship outcome consists of the CE, PV, CC, GCR, and HRB scales.

Table 3: Mapping between interventions, GES student outcomes, and project

Global Engagement intervention	**Explain how issues of social justice, power and privilege are shaped in a variety of contexts.**	**Express respect and thoughtful engagement with people across cultures**	**Use language and knowledge of other cultures effectively and appropriately to communicate, connect and build relationships with people in other cultural communities.**
International case study	X		X

Multi-national student teams		X	X
COIL project	X	X	X
Engineering course with community engaged project	X	X	X
	Global Citizenship	**Cultural Humility & Critical Reflection**	

4.2. GES - Qualitative

Due to the non-compulsory nature of the qualitative questions, all responses across interventions were consolidated into a single dataset for a comprehensive thematic analysis. Five prevalent themes were identified that capture the students' intercultural engagement experiences: *Communications, Work Ethic, Individual Identity, Life Experience, and Adaptation*. These themes were selected from the collective insights of the faculty members who independently reviewed the combined dataset. This analysis highlights the multifaceted challenges and learning opportunities students encounter when navigating the complexities of global engineering environments. These themes are further defined in Table 4.

Table 4: GES qualitative coding themes

Code	Coding Theme	Definition
1	Communications	Response includes major themes around spoken language, non-verbal communications, judgment/perception, temperament, and/or forced/informal communications
2	Work ethic	Response includes major themes around meaning of time, organization, procrastination, work quality, workload distribution, and/or power differential
3	Individual identity	Response includes major themes around cultural norms, human rights, morality, faith, personality, traditions, learning style, and/or impact of demographic variables such as gender, age, sexual orientation, and/or race
4	Life experience	Response includes major themes around ignorance or denial, experiences or lack of, knowledge, empathy, and/or closed minded

5	Adaptation	Response includes major themes around being open to new ideas, flexible, open to discuss topics outside their comfort zone, open to learn from different people, open to engage with people of different backgrounds, and/or open to learn a new language

The engineering faculty members assessed the qualitative responses from their own intervention and one additional intervention, allowing the team to test for inter-coder reliability. Through this qualitative assessment a few key results were found.

- There were insufficient responses for many of the questions when the dataset was broken down by intervention.
- The responses were often short, incomplete, or ambiguous.
- The common themes identified mirrored the key variables of the GES.

4.3. GECS

Matched data from the pre and post GECS assessments of the four global engagement interventions was reviewed. For each matched pair, the change in score from pre to post assessment for the GECS cognitive scale and the GECS behavioral scale was calculated and is shown in Figures 1 through 4 for each of the global engagement interventions.

5. Spring 2023 Intervention Summary Findings

Results from the assessment data from the spring 2023 pilot are presented in Figures 1 through 4 for each of the individual interventions.

5.1. International Engineering Case Study in a Quantitative Analysis Course

The mean change in each GES and GECS scale resulting from the case study intervention is shown in Figure 1. Positive changes were observed for Cultural Adaptability, Political Voice, GECS cognitive, Civic Efficacy, and Conscious Consumption (largest increase). Given the nature of the intervention (research, discuss, plan), positive movement in these scales seems appropriate. The intervention effectively improved competencies related to critical thinking in a global context. It is also worth noting that the scales showing positive movement had the lowest pre-intervention scores. Scales showing 0 or negative changes were the scales that had the largest pre-intervention scores.

The number of students enrolled in Quantitative Analysis was lower than expected. Of the 9 students who were enrolled, 1 was also enrolled in the international breakout, and 5 were international students. As international students in the US, they were effectively in the middle of their own international breakout experience when participating in this intervention. This implies that the data for the case study may be confounded and not a true representation of the effectiveness of the intervention. Efforts have been made to increase enrollment in Quantitative Analysis for the next implementation.

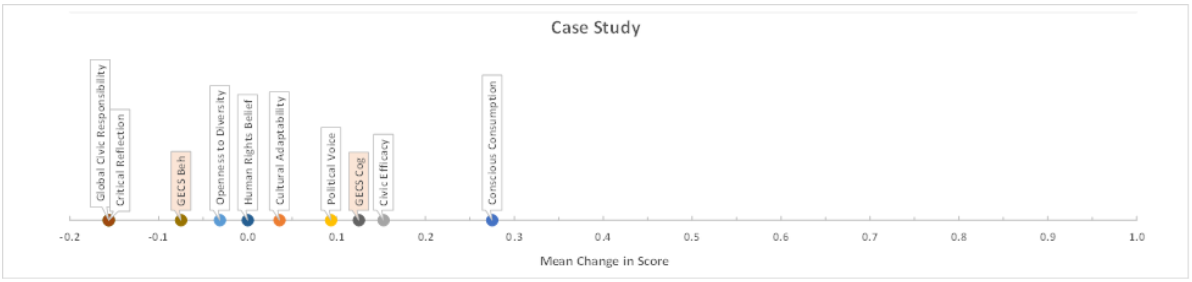

Figure 1: Mean change in GES and GECS scores for case study intervention

5.2. Intentional Formation of Multinational Student Design Teams Within a Capstone Design Course

Mean changes for the Multinational Student Design Teams intervention are shown in Figure 2 and highlight the mixed results of the intervention. Positively, it enhanced students' Openness to Diversity and Global Civic Responsibility, as well as their cognitive and behavioral understanding of global engineering practices, evidenced by increases in GECS Cognitive and Behavioral scores. This suggests the intervention was effective in broadening students' global perspectives and their ability to apply these insights practically.

However, the intervention also revealed areas needing improvement. Notably, there was a decrease in Cultural Adaptability and Civic Efficacy, indicating challenges in adapting to diverse cultures and a reduced sense of impact in global contexts. Additionally, declines in Human Rights Belief and Critical Reflection point to a need for more focused efforts in fostering a deeper understanding of global issues. While the intervention had successes, these findings highlight the need for a more balanced approach in future iterations to fully develop students' global engineering competencies.

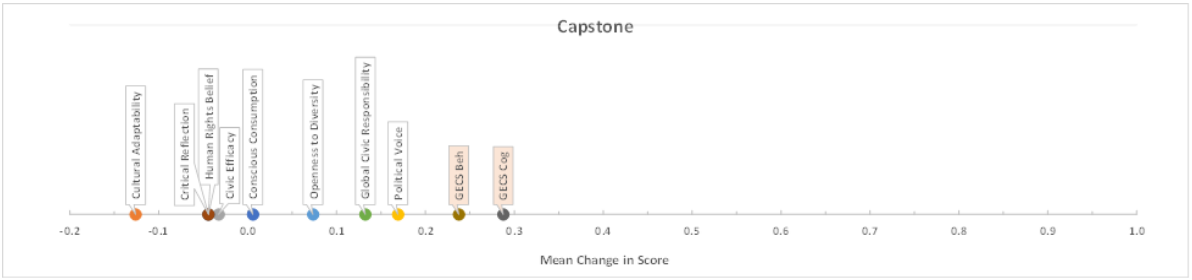

Figure 2: Mean change in GES and GECS scores for capstone teaming intervention

5.3. COIL Research Project in a Transport Phenomena Course

Results for mean changes for the COIL intervention are shown in Figure 3. The most significant change was observed for the GECS cognitive component, with an increase of 1 point. The GECS behavioral aspect had a negligible change at a high mean value. In a control group where students did the COIL activity, but only among US students, there was a change in the GECS cognitive and no change in the GECS behavioral. These results suggest that the COIL activity significantly impacted the GECS cognitive scale. Evaluating individual survey questions may

serve to understand specific changes achieved with the COIL activity and students using the GECS.

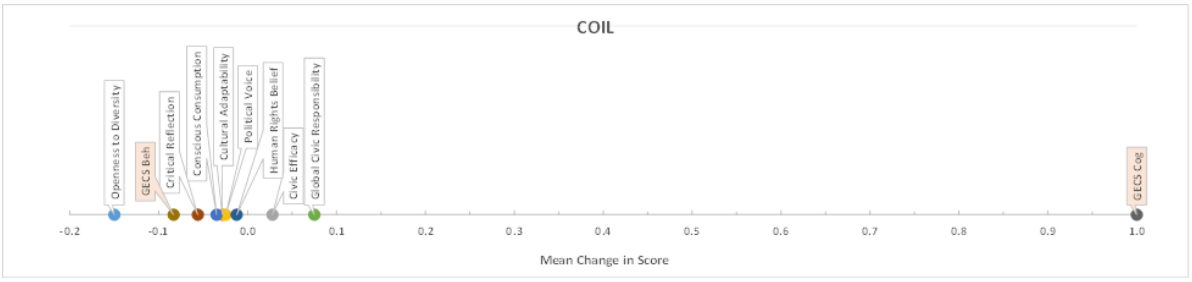

Figure 3: Mean change in GES and GECS scores for COIL intervention

5.4. Engineering Course Coupled to a Community Engaged Project

As observed in Figure 4, the intervention appears to have a significant impact on developing the global mindset and global engineering competency of students with a net positive score change across all GES and GECS scales. Additionally, it is noted that as an elective course and associated breakout, the participating students had elevated mean pre scores across most of the scales.

The GES scale with the smallest score change was human rights belief, however, it had the highest mean pre score of 4.5, perhaps with little room for growth. It was also noted that openness to diversity also had a high mean pre score of 4.03, however, it had the second highest mean change in score. Overall, the mean post score for all scales except political voice and conscious consumption were over 4.0.

For the GECS assessment, students showed over twice the mean change in the cognitive domain in comparison to the behavioral domain. It should be noted that the mean pre behavioral score of 4.18 was significantly higher than the pre cognitive value of 3.02, potentially indicating little room for growth in the behavioral domain. The post GECS behavioral and cognitive scores were much closer at 4.69 and 4.0, respectively.

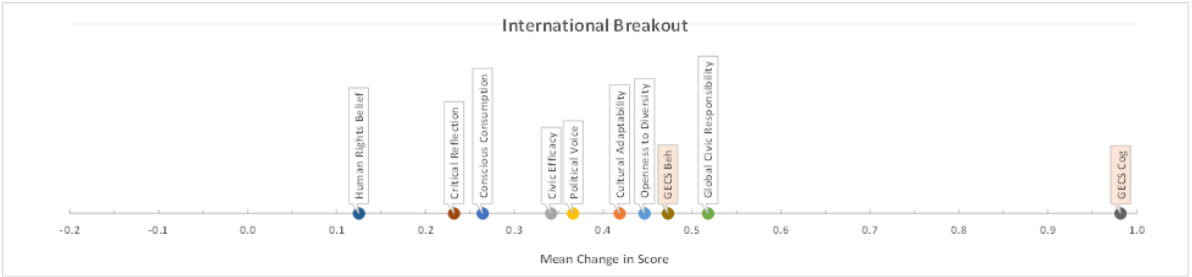

Figure 4: Mean change in GES and GECS scores for community engaged project intervention

6. External Advisory Board Meeting

The research team held a virtual meeting with the project's external advisory board members after they completed their analysis of the spring 2023 semester data and made tentative plans on a path forward for the next implementation of the interventions and the associated assessment strategy. During this meeting, they shared a summary of the assessment results and posed a series of questions mainly focused on the assessment strategy. Specifically, the team was interested in gaining the advisory board's feedback on the current qualitative questions within the GES, the potential development of additional qualitative instruments, including using a focus group, and how best to understand the quantitative change scores. From this discussion, the team was able to refine their assessment approach for the next iteration of the interventions.

7. Next Steps

The research team used observations from the Spring 2023 implementations and the assessment results to update and modify each intervention. These modified interventions will be implemented in Spring 2024, with subsequent data analysis in Summer 2024. Data analysis will explore the differences between the interventions as well as the changes observed from Spring 2024 to Spring 2023. To better identify the impact of each intervention, additional qualitative questions will be added to the post-implementation survey and focus groups composed of Spring 2024 students will be assembled and interviewed. Qualitative responses will again be coded and analyzed to identify themes and the impact of each intervention on the global engineering skillset. Results from this assessment will provide insights regarding the strengths and weaknesses of each intervention and ultimately lead to future engineering curriculum recommendations.