

## **Global Engineering Competencies Learned Through Virtual Exchange Project Collaboration**

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### **Abstract**

A virtual exchange involving 133 undergraduate STEM students in the US, Lebanon, Denmark, and Nepal was completed in the Summer of 2020. The goal of the program was to guide students through a collaborative design process where they experience working productively with people whose cultural backgrounds were different from their own.

Groups of 4-5 students worked with a facilitator over 5-6 weeks. The course has an asynchronous and synchronous component to accommodate different time zones and schedules. A series of 5 video lectures guided students' learning along the design path. The students were directed to download a set of notes with blanks and encouraged to actively listen by filling in the notes while watching the lecture. The length of the video lectures ranges from 8 - 32 minutes. A set of 5 individual assignments (in the form of on-line quizzes) were created to support the asynchronous activities. After watching the video lecture, students are directed to complete a quiz. Responses to short-answer questions covered in the lecture and reflective exercises are collected. Students are given 1 week to complete the activity which can be asynchronously. For each of the 5 weeks the student team also worked on group assignments. Models and templates of the group assignments were created to help the student teams respond to the open-ended design process. The culminating activity for the team was to create a video presentation describing their healthcare innovation and the supporting research collected during the program.

IRB approval was obtained, and subject informed consent was requested as a prerequisite to participation in this study. A global competency survey regarding "Cross-Cultural Collaboration" was requested from each participating student at the beginning and end of the program. Students were invited to participate in a one-on-one interview, and artifacts associated with the design process (both individual and group assignments) were collected.

This paper discusses the students' assessment of the growth in global competency and collaboration skills. the transition from an in-person to a remote learning program, lessons learned from virtual exchange, and suggestions for future program designs.

## Introduction and Background

It is well understood that teamwork is integral to the engineering discipline and also a valuable skill for engineering students to acquire and hone. The Accreditation Board for Engineering and Technology, Inc. (ABET), requires that students demonstrate “an ability to function on multidisciplinary teams” [1]. In a systematic study of educational research, Passow and Passow [2] found that ‘Technical competence is inseparably intertwined with effective collaboration’. That is, communication and collaboration skills are just as important as problem solving skills to the engineering process.

Increasingly, educators and industrial leaders have recognized that engineering students also require a new set of skills to be successful in solving global problems that have developed in an interdependent world [3]. Parkinson et al [4], has described 13 specific skills or abilities as collectively “global competencies”. Among the most important of these skills are:

- 1) an ability to appreciate other cultures,
- 2) an ability to work proficiently within a team of ethnic and cultural diversity,
- 3) an ability to communicate across cultures,
- 4) experience practicing engineering in a global context, and
- 5) an ability to effectively deal with ethical issues arising from cultural or national differences

Traditionally, these skills are acquired through study abroad programs. Recently some courses have been developed for undergraduate engineering students with some success demonstrating students’ increased global competencies even among students were are not able to travel, see for example [5].

This paper will report on the experience learned from a program that was developed to provide opportunities to practice engineering in a global context. The Engineering World Health Virtual Exchange was developed and conducted in the summer of 2020 by the Engineering World Health organization [6] and supported by the Stevens Initiative Coronavirus Response Fund [7]. At the height of the COVID-19 pandemic. At a time where most study abroad opportunities around the world were canceled due to health and safety concerns, undergraduate students from multiple disciplines and multiple universities were recruited to form international teams comprising members from the US and Lebanon. A sister program also was conducted in the same summer with students from the US, Denmark, Norway, and Nepal. The programs’ unifying theme was to create innovative solutions to health care problems in low-resource settings.

Virtual teams, those that never have met in person and collaborate entirely on-line, face additional challenges to communication and collaboration. There might a language barrier, a lack of visual cues to aid communication, a lack of shared understanding and trust, logistical issues associated with geographically diverse members (e.g., time zone differences), and an unbalanced access to technology [8]. We seek to learn how effective the virtual team experience can be to improve student’s global competencies.

## Purpose and Research Questions

The goal of the virtual exchange program was to guide students through a collaborative design process where they experience working productively with people whose cultural backgrounds were different from their own. Long-term we want to know if these types of virtual exchange programs can significantly increase a student’s global competency skills, if the experience makes

it more likely that the student will participate in a future in-person exchange or physical global experience, and if the skills learned through collaborating with a highly diverse team lead to increase teaming skills that better prepare the student for future teaming tasks.

In this paper we describe the implementation of the Engineering World Health Virtual Exchange program. We describe the student activities and the role of the team facilitators. Next, we present the student participant demographics. Finally, we report on impact of the program on the students global competencies skills as measured by pre-and post- self-assessment survey of global team collaboration attitudes.

### Virtual Exchange Implementation

The Engineering World Health Virtual Exchange is an international collaboration of university STEM students, working together to create innovative solutions to healthcare challenges in low-resource settings. Led by engineering faculty and facilitators, participants worked in teams to identify needs and design innovative solutions. International teams of 4-5 students were formed and matched with a team facilitator who also acted as a technical mentor. The culminating activity of the virtual exchange is a video created by each team describing their healthcare innovation and the supporting research collected during the program.

The student learning objectives for the virtual exchange were:

- 1) Develop a solution to an open-ended problem, demonstrating creativity and innovation.
- 2) Given an open-ended question or problem, be able to discuss the problem constraints or contextual factors (ethical, cultural, political, and/or social) of the problem using appropriate evidence.
- 3) Interpret an intercultural experience, taking into account the values, assumptions, and/or practices relevant to the culture(s) involved.
- 4) Work with a team to address a community challenge that requires technological skills, relationships, and act to solve that community challenge.

### Recruiting

An open enrollment process was used to recruit undergraduate STEM students from the US and Lebanon for cohorts 1-4. The 5<sup>th</sup> cohort focused recruiting from Nepal and the Nordic Five Tech universities in Denmark, Finland, Norway and Sweden. The program was free to the students. Students were encouraged to apply through a website application process. The expected time commitment was advertised as 4-6 hours per week with flexible hours for participation, allowing students to participate even if they had internships, jobs, or summer classes. The program opportunity was announced through email listservs and the Engineering World Health website. The US-Lebanon program filled to capacity within 1 week. Recruiting was more successful among the Nepal students than the Nordic students. Due to lower than expected participation among the Nordic Five Tech students, some US students who were on the waiting list for the US-Lebanon program were added to the team rosters of the Nepal-Nordic program.

To manage the facilitators' time, the teams were formed with a staggered start date in 5 cohorts, 1 week apart. A total of 30 teams went through the 5-week program and another 6 teams went through a 6-week program spread out through the months of June, July, and August as described in Table 1 below. Teams were formed with 4-5 students with the intent to mix gender and nationality evenly.

| Cohort | Number of teams / Number of students | Start date in the year 2020 | 5-week or 6-week program |
|--------|--------------------------------------|-----------------------------|--------------------------|
| 1      | 6 / 24                               | June 22                     | 5 week                   |
| 2      | 6 / 23                               | June 29                     | 5 week                   |
| 3      | 6 / 28                               | July 6                      | 5 week                   |
| 4      | 6 / 29                               | July 20                     | 5 week                   |
| 5      | 6 / 29                               | July 20                     | 6 week                   |
| Totals | 36 / 133                             |                             |                          |

**Table 1 Summary of student participation in the virtual exchange programs.**

### Student Activities

Over the summer, participants met with their team virtually twice a week for 5 or 6 weeks (depending on the program). The facilitator worked with the team to initiate brainstorming, conceptual design development, stakeholder analysis, and technical feasibility studies. The facilitator organized the meetings among the students. Times were selected so that all members could attend. Sometimes the teams were able to meet at regular times other teams had to set meeting times in an ad hoc manner to accommodate the student work or class commitments. All the meetings were conducted in English. English was a second language for about half of the participants.

Students were encouraged to watch 5 video lectures, one on each week of the program. The subjects were:

- 1) an introduction to global health technologies,
- 2) conceptual design procedures,
- 3) functional architecture process,
- 4) technical feasibility examples, and
- 5) a global engineering case study of the Jaipur Foot [9].

For each video lecture, a copy of notes was provided for download and students were encouraged to print the figures and take notes while watching the video. The video lectures ranged in length from 8 to 32 minutes. The video lectures were in English with English sub-titles. The students were asked to complete reflective exercises in the form of “quiz” where they can type their answers into an electronic form. All course materials including quizzes were made available through the Google Classroom™ learning management system [10].

To facilitate collaboration within the team, each week the team was required to complete a group assignment. The group assignments were designed to help the team with communication and collaboration on the design project.

The assignments were:

- 1) a team biography
- 2) a global health problem statement or need that is to be addressed by the team’s design

- 3) a functional architecture or block diagram describing the team's design solution
- 4) some evidence of technical feasibility or proof of concept study of the design
- 5) a final presentation slide presentation of the team's work

#### Role of the team facilitators

A total of 7 facilitators worked with 3 to 6 teams. Facilitators were either engineering faculty (2), graduate engineering students (2), or professional engineers with at least 5 years' experience (3). Two of the facilitators were in Lebanon, the rest were US-based. Facilitators met for 1 hour once per week to coordinate activities and share best practices. The role of the facilitator was two-fold: to help the communication among the team, and to act as a technical mentor aiding the team in the completion of their design project.

#### Data Collection

The purpose of this assessment project is to determine if a short-term, multinational, virtual team experience will enable students to work effectively as a team to define and solve an open-ended problem with an effective design.

Student surveys were requested at the beginning and end of the project to complete a short survey that evaluates their Cross-Cultural Collaboration attitudes [11] Survey Monkey was used to collect the survey data from the student participants. Students were sent a link by email asking for their voluntary participation. The survey took less than 5 minutes. At the start of the survey the risks and benefits were explained on Survey Monkey. Study participants were asked to give their consent by checking a box and selecting to start the survey. The email address were used to track the respondents in order to pair the pre- and post-survey responses. The survey was set-up and monitored by an Engineering World Health professional who was not part of the research and had not interacted with the students during the virtual exchange as a facilitator. The students' facilitator did not know which students completed the survey. After data were matched, the data matching the unidentifiable study ID to email were deleted. All analysis was conducted using unidentifiable study IDs.

The Cross-Cultural Collaboration (see Table 2) survey was chosen because it was relatively short and addressed attitudes and skills associated with the team work that was the focus of our student learning objectives. The Pre-survey questions were repeated in the post survey. In addition, students were asked to make reflective assessments about their own attitudes regarding collaboration experience. The response choices were shown using a 5-point Likert Scale: strongly disagree, disagree, neither agree nor disagree, agree, strongly agree. Questions 5-7 were reverse coded. It was not possible to submit a completed survey without answering all the questions, therefore none of the responses were left blank.

|   | Pre-survey Questions  | Post-survey reflective Questions   |
|---|---|--|
|   | <i>Please indicate how much you agree or disagree with the following statements</i>                   | <i>Now think back to before you started the virtual exchange program, and please indicate how much you agree or disagree that the following statements described you <u>then</u></i> |
| 1 | I like to learn about people from other cultures so that we can work together.                        | I liked to learn about people from other cultures so that we could work together.  |
| 2 | I am confident that I can produce work with people from other places around the globe.                | I was confident that I could produce work with people from other places around the globe   |
| 3 | I am able to adjust to new people, places, and situations.  | I was able to adjust to new people, places, and situations.  |
| 4 | I can work productively with people whose cultural background is different from mine.                 | I could work productively with people whose cultural backgrounds were different from mine.   |
| 5 | Groups usually produce better results when they are made up of people who all see things the same way | I believed that groups usually produce better results when they are made up of people who all see things the same way.   |
| 6 | I prefer working with people who think the same way I do.   | I preferred working with people who thought the same way I did.  |
| 7 | I am most comfortable working with people who look and act like me.                                   | I was most comfortable working with people who looked and acted like me.   |

Table 2 List of questions used in the pre- and post-survey.

All students (133) were asked to take part in the pre and post survey. The response rate varied from 26-34% as described in Table 3.

| Number of completed surveys and response rate |        |     | Gender *       |                | Nationality<br>US/International percent |                |
|---|--------|-----|----------------|----------------|---|----------------|
|   |        |     | Male           | Female         | US                                      | International  |
| post-survey                                   | 45/133 | 34% | 13/45<br>(29%) | 24/45<br>(53%) | 19/45<br>(42%)                          | 26/45<br>(58%) |
| matched pre & post - survey                   | 34/133 | 26% | 10/34<br>(29%) | 18/34<br>(53%) | 14/34<br>(41%)                          | 20/34<br>(59%) |

Table 3 Response rate of student participants. Gender was not consistently collected for cohort 5. If the gender was unknown it would not be counted in the male/female rate so the percentages do not add up to 100%.

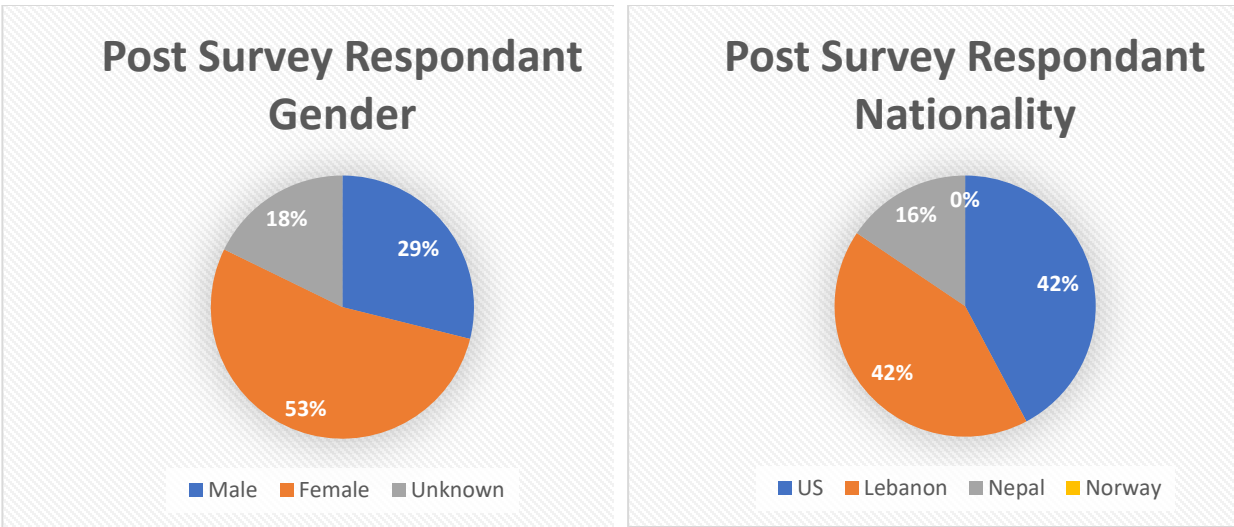


Figure 1 Gender and Nationality proportions in the dataset containing all student who responded to the post-program survey.

All students (133) were asked to take part in a one-on-one informal interview (approximately 20 minutes) with an EWH professional who has not personally been part of the team that has interacted with the students. However, only 5 interviews (3% response rate) were collected. Students were informed, and their consent will be requested for the interview by email prior to questioning. Students were reminded at the start of the interview that they can choose not to answer any questions and they can be asked to quit the study at any time.

#### Assessment of Students' Global Competency Skills

To assess the global collaboration skills, we focused our analysis on the dataset where respondents completed both the pre- and the post-program survey. Figure 2 shows the average response to each question in the pre-survey, the post-survey, and the questions that students were asked in the post-survey where they were asked to reflect on their experience at the beginning of the program (called post-reflective). Among respondents most participants were agreeable (average response > 3.0) when asked to comment on their interest and ability to work with people from other cultures as indicated by the average response for question 1-4. Questions 5-7 were reverse coded answers and the responses on average demonstrated that students recognize the value of working with people that different from themselves. This result may not be surprising because the virtual exchange program was an optional activity and would be highly attractive to students who already valued opportunities for global learning. From the post-survey responses, we see an enhancement in all areas that were measured. The student post-reflection responses seem to track their actual pre-program responses well.



## Assessment of Collaboration Skills Before and After Virtual Exchange

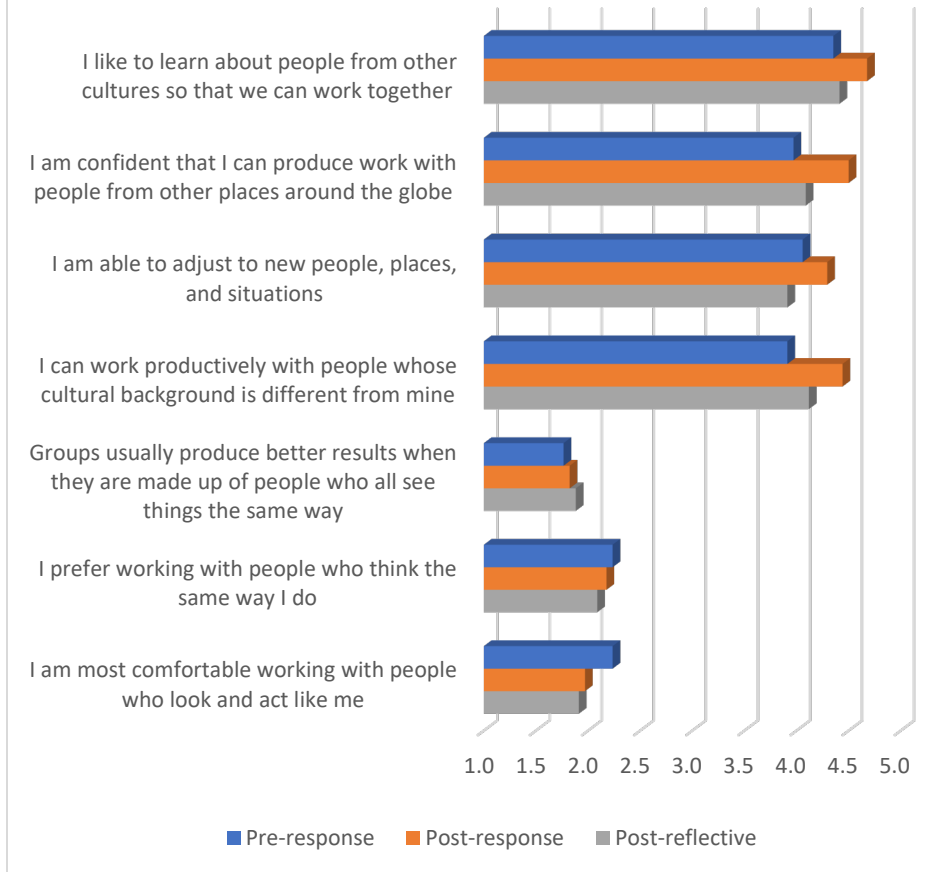


Figure 2 Results from Cross-Collaboration Survey

### Statistical analysis

We first tested the reliability of the data by computing the Cronbach-alpha score (0.76). A score between 0.7 and 0.8 or higher is considered to be internally consistent. We next looked to see if there were significant differences in the distribution of responses between pre- and post-survey questions and between the post-survey and post-reflective survey.

We used a t-test to test the null hypothesis that the pairwise difference between how students responded to the survey questions at the beginning of the course (pre-survey) and at the end of the course (post-survey) has a mean equal to zero. Table 4 reports, for each question, the results of the t-test and the significance as measured by the p value. A p-value <0.05 is generally considered statistically significant (those t-test that are significant are highlighted).

| Survey Questions  | 1. I like to learn about people from other cultures so that we can work together | 2. I am confident that I can produce work with people from other places around the globe | 3. I am able to adjust to new people, places, and situations | 4. I can work productively with people whose cultural background is different from mine | 5. Groups usually produce better results when they are made up of people who all see things the same way | 6. I prefer working with people who think the same way I do | 7. I am most comfortable working with people who look and act like me |
|-------------------|--|--|--|---|--|---|---|
| Pre - post        | reject   | accept   | reject   | accept  | reject   | accept  | accept  |
| p value           | < 0.001  | 0.505  | 0.031  | 0.080   | 0.014  | 0.629   | 0.090   |
| post - reflective | accept   | accept   | reject   | accept  | accept   | accept  | reject  |
| p value           | 0.748  | 0.526  | <0.001   | 0.167   | 0.125  | 0.162   | 0.004   |

Table 4. Results of t-test for significant differences in the survey results.

Of the pairwise differences, 5 of the 8 questions were determined to be significant. In questions 1, 3, and 5, the null hypothesis that the results were not significantly different was rejected, meaning and there is a significant (not due to chance) reported enhancement in the students' assessment of: how much they like to learn about people from other cultures (question 1), how they feel they are able to adjust to new situations (question 3), and whether they feel homogeneous groups are more productive (question 5). The null hypothesis was accepted in question 4 and 7, which means there was no significant difference found between the pre and post responses to these questions. Nothing can be inferred from the pairwise difference of question 2 and 6 due to a lack of significance in the t-test ( $p > 0.05$ ).

We also tested the null hypothesis that there was no significant difference between the students post and post-reflective answers to the survey questions. Here we are relying on the students to accurately think back to how they felt as the beginning of the program. We found further evidence that the pair-wise difference between the students' responses describing their self-assessment of their ability to adjust to new people places and situation was improved over the 5 week program. The rejection of the null hypothesis in question 7, seems to indicate that upon reflection the students did feel a difference in their comfort level, however their responses before and after the program did not indicate a difference in their comfort level. This may be a result of how the question was asked and a reluctance on the students' part to be disagreeable in the pre-survey and a predilection to see themselves as improving when they reported their answer in the post-survey reflection questions.

### Lessons learned

Several activities needed to be completed well in advance of the program to make it successful. Since this grant opportunity was in response to the Coronavirus the time schedule for preparation was compressed. Ideally, the program goals and student learning objectives would be finalized

first. The design of the assessment of the program must be finalized before the IRB application is submitted. Ideally this would happen before the program has begun (at least 2 months should be planned since some IRB committees only meet monthly). In our case, we did not have this advanced time and had to wait until after the program started before administering the pre-program survey. Since we had a staggered start, this was delayed for about 20% of the students.

We made pre-recorded video lectures and posted them on a google classroom which was free and easy to access for students in the United States, Lebanon, and Nepal as long as WiFi was available. Since the students were not in school and mostly at home during the lockdowns, WiFi access was limited. We found that some students could not access WiFi because there were local power outages. Most were able to compensate with access through their cellular service, but it cost them additional money to pay for more data. We started to provide individual hot spots to some students who demonstrated a need.

We had a small number of facilitators, all trained in engineering, and two of us were experienced educators. We think the synchronous sessions were successful because the facilitators met weekly and shared ideas and experiences. We feel the facilitators could be better prepared if we generated specific ideas for the goals and agendas of each synchronous team meeting. We also found that some groups wanted to talk about non-technical issues related to social and political current events (especially after the explosion incident in Lebanon). These off-topic discussions were encouraged if not planned. We feel that facilitators in the future could be better prepared if we gave them some tools or practice in moderating discussions with respect in difference.

We think that higher study response rates could be achieved if the students were given time during the synchronous meetings and directed to respond to the email request by their facilitator. The students will be asked to complete the surveys in order to evaluate the program and at the end of the survey they would be asked if they volunteer to have their data included in the research study. It will be important to make sure the research faculty does not share a dual role as facilitator and the facilitator makes it clear to the students that they will not know whether they students agree to take part in the research study or not. Informed consent would be described at the end of the survey with an opt-in button.

## Conclusions

It can be particularly challenging to design remote learning tools that are appropriate for the context when the intended user is from an unfamiliar society. The motivation to train students to work on diverse multinational teams is to prepare them to innovate appropriate designs for cultures that are different from their own experiences. This motivation creates a basis of shared understanding and common team goal; a basis on which to build team collaboration. We find that the virtual teaming experience provides ample opportunity to improve student global competency skills among undergraduate STEM students, at the same time broadening the participation by reducing barriers related to travel and costs.

Based on our analysis, the findings indicate that some modest improvement in the skills and abilities associated with cross-cultural collaboration was achieved through this short-term virtual exchange program.

It is interesting to note that on August 4, 2020 Lebanon suffered one of the largest accidental explosions, causing the death of at least 220 people, thousands were injured and hundred of thousands were left homeless [12]. Although none of our Lebanese students or facilitators was

seriously injured, all of them felt the effects of the profound national tragedy. We witnessed many of the US students reach out to their Lebanese teammates with sincere expressions of sympathy.

We note that the gender breakdown among the participants in the virtual exchange program was significantly different from undergraduate engineering student demographics. A higher percentage of women are in this group than you might find in a typical engineering classroom in the United States, Lebanon, and Nepal. It could be the global exchange opportunity was interesting to women or the topic of improving global health in a low-resource setting provided the incentive. In the future, it would be interesting to learn more about the motivations among the students for taking part in program.

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