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Applying a Collaborative Online International Learning Experience (COIL) during two Undergraduate Environmental Engineering Courses in the US and Mexico

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Abstract

The ability to communicate effectively and to work in multidisciplinary teams with individuals from diverse international backgrounds are some of the student outcomes that need to be met by academic programs seeking accreditation by independent organizations such as ABET. International course collaborations able to fulfill these goals are challenging under regular conditions, but the COVID-19 pandemic and the migration to virtual learning in both Mexico and the United States presented an opportunity to test multinational collaboration during a regular course context. In the Fall 2021, we piloted a month-long collaboration between two engineering courses at Rice University (US) and Tecnológico de Monterrey (Mexico). This collaboration was designed to meet the two student outcomes stated above in the context of UN Sustainable Development Goal 6 using COIL. A series of activities were designed to promote student reflection on topics such as the cultural, social, and technical factors related to the design of a rainwater collection system. Examples of these activities include discussion sessions prompting the exchange of ideas by students from both institutions, and mutual evaluation of their rainwater harvesting designs. At the end of the collaboration, the students completed a survey reporting their understanding of the current global water crisis, the challenges to provide sustainable solutions, and their perception of the collaboration. Due to differences in both courses, such as accessibility and quality of internet access, the personal goals of the students and the language barrier, the authors obtained mixed reactions from the students to this collaboration. Most students reported that this experience was positive, provided new knowledge and an opportunity to develop their international collaboration skills; only a few students reported no positive outcomes. Although this first collaboration proved to be satisfactory for both students and instructors, it also provided several learning opportunities, such as forming smaller work groups to allow the students to connect at a more individual level, providing TAs to be present in every discussion room to encourage participation of all students, and emphasizing the need for more cultural awareness, such as the fact that some participants are not having these discussions in their native language.

Introduction

The ability to communicate effectively and work in multidisciplinary teams with individuals from diverse international backgrounds are student outcomes that need to be met by academic programs seeking accreditation by independent organizations such as ABET (e.g., ABET Student Outcomes (g) an ability to communicate effectively, and (h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context) [1]. The rise of virtual communication tools and virtual learning, especially during the COVID-19 pandemic, have made Collaborative Online International Learning (COIL) experiences a more achievable and cost-effective option for multinational collaboration during a regular course context.

According to the SUNY COIL Center, COIL "is about connecting across difference" [2]. In this approach, professors and students in different courses and different countries develop and work

in collaborative projects across geographical distance, cultures and language differences using online tools. As part of a course, the COIL experience supports student learning goals, and allows participants to engage with the course themes and concepts from different cultural perspectives [2].

A well-designed COIL experience is composed of four progressive stages [2]:

1. Team building: students introduce themselves and engage in icebreaker activities.
2. Team organizing: students engage in comparative discussions and organize the project work.
3. Project work: students work on their common project.
4. Closing stage: students present their work and reflect on the multicultural interaction.

The goals for this collaboration were to pilot a COIL experience in the Fall 2021 between two courses, to improve the students' international communication and collaboration skills, and their understanding of water availability, rainwater harvesting and treatment in the US and Mexico, and Sustainable Development Goal (SDG) 6: Ensure Availability and Sustainable Management of Water and Sanitation for All [3].

Courses and COIL experience descriptions

Course descriptions

At Rice University (Houston, TX, US), the course involved in the COIL experience was CEVE 314: Sustainable Water Treatment for the Developing World. This course is an overview of sustainable strategies for safe water supply in low-resource areas of the world. Topics covered include the selection of appropriate clean water supply systems adapted to local conditions, water quality and WaSH (water, sanitation, and hygiene) issues, and small-scale water purification technologies. A major element of the course is a project to design a solution to a real-world problem related to the provision of safe drinking water in a developing region. The course was held in person during the COIL experience.

A total of 19 students matriculated in CEVE 314 in the Fall 2021, of these, 14 identified as female and 5 as male. Most of them (18) were seniors and 1 was a junior. The most commonly represented major was Civil Engineering (7 students), followed by Mechanical Engineering and Bioengineering with 2 students each. The following majors were represented by 1 student each: Civil and Environmental Engineering, Chemical Engineering, Computational & Applied Mathematics, Materials Science & Nanoengineering, Biological Sciences, Biochemistry & Cell Biology, Kinesiology, and Sport Management.

At Tecnológico de Monterrey (Puebla, Mexico), the course was CV 2030: Sustainable Water Use, which is taught in English and was held online during the COIL experience. This course is composed of five modules: General worldwide water situation overview, Human water use, Drinking water treatment, Municipal Wastewater treatment and Sludge treatment. It is part of the curriculum of Civil (5th semester), Sustainable (7th semester) and Biotechnological (9th

semester) Engineering. In addition, students from other engineering and non-engineering majors registered for the course. In the Fall 2021, 19 students registered, 5 identified as female and 14 as male. Majors represented were: Civil Engineering (11 students), Mechatronic Engineering (2), Biotechnological Engineering (5) and International Relations (1).

COIL experience learning outcomes

The learning outcomes for the COIL experience were:

1. Students will improve their ability to understand, communicate, and work with peers of diverse cultures by sharing perspectives on a specific issue related to the SDGs.
2. Students will become familiar with organizational and academic aspects of academic cultures other than their own.
3. Students will improve their ability to collaborate with international peers on a common project through virtual communication and learning platforms.
4. Students will recognize the importance of water quality and quantity.

COIL experience structure and implementation

Planning

Planning of the COIL experience occurred during the two months before the start of the semester. The two instructors from both universities (Rice & Tecnológico de Monterrey) met weekly for an hour and collaborated online to build the COIL curriculum and prepare the materials to be shared with the students. In addition, a facilitator from the International Collaboration Office at Tecnológico de Monterrey collaborated with the instructors by providing materials such as calendars and templates, and by providing feedback on the COIL materials during a 90-minute online session.

Implementation

The COIL experience with students from both institutions took place during 4 weeks in the Fall semester of 2021 and was conducted in English. The students were placed in teams within their own institutions, and each team was matched with a counterpart at the other university for the COIL work. There were 5 teams with 4 students from Rice University and 4 students from Tecnológico de Monterrey, for a total of eight students per COIL team. These mixed teams held synchronous weekly discussions of 50 minutes each and engaged in online collaboration during the week. The four progressive stages of the COIL experience were applied:

1. Team building: icebreaker activity
2. Team organizing: comparative discussion
3. Project work: collaborative project work
4. Closing stage: project presentation and final reflection

The icebreaker activity consisted of an in-class slide presentation, where each team member introduced themselves to their teammates using 1 or 2 slides prepared in advance containing basic information, photos and images, and a few fun facts about themselves. Examples of prompt questions were: Where are you from? What is your major? What do you do in your free time? Have you had any international experiences?

The comparative discussion and project work were weekly activities, where the students had to complete two pre-class tasks, an in-class discussion, and post-class task.

Pre-class tasks included:

1. Watching two videos, one on social and/or cultural issues related to the acceptance and development of water technologies in low-resource communities, and the second on a technical topic related to water treatment.
2. Answering four to five questions provided by the instructions about the videos and writing a personal reflection on the main takeaways in order to discuss them in class.
3. Project work: Researching and designing different parts of the technical project.

Each team had access to a Google document containing the description of the week's theme and activities, instructions for the activities, and due dates.

The project consisted of the design of a rainwater collection and treatment system. Due to the differences in nature and content of both courses, and the fact that Rice University students were all in person at the university and able to work together, whereas students at Tecnológico de Monterrey were working from home in different cities in Mexico, the context for their designs was different. A 4-student team from Rice designed a rainwater collection and treatment system for their dormitory on the campus located in the City of Houston, and a 4-student team from Tecnológico de Monterrey designed a system for their own homes in Mexico. The collaborative part of the project occurred at the COIL-team level, where one team from Rice and one from Tecnológico de Monterrey shared their design ideas, evaluated each other's progress in the design, and provided feedback to their counterparts.

All students followed the same engineering design process steps and were assigned the same design tasks. Throughout the COIL activity, the students shared information on different types of rainwater collection and treatment systems, compared regulations for rainwater harvesting in both countries and rain patterns in different geographical areas, as well as their designs through shared Google Documents folders. The final deliverable was a presentation on their final system design.

In-class discussions took place every week, with all the students and instructors in a Zoom meeting room. The sessions were divided into 5 sections: a brief introduction to the week's topic (2 minutes), instructions for the week's discussions (1 minute), a brief Q&A session (2 minutes), teamwork in breakout rooms (40 minutes) and a brief "final thoughts and conclusions" session in the main room (5 minutes)

Table 1 shows the weekly topics and activities due each week, and the weight given to each individual activity in the overall COIL experience grade.

Table 1. Structure of the COIL experience including weekly topics and activities, and the weight of each activity in the COIL grade.

Week	Weight (%)	Topics	COIL stage
Week 1: Rainwater availability	5	In class discussion: Introductions	(1) Ice breaker
	15	Water availability	(3) Project
	5	Discussion: water quality videos	(2) Comparative discussion
Week 2: Rainwater harvesting systems	5	In class discussion: Second week reflection	
	15	Rainwater harvesting system	(3) Project
	5	Discussion: social aspects videos	(2) Comparative discussion
Week 3: Water treatment	5	In class discussion: Third week reflection	
	15	Drinking water treatment	(3) Project
	5	Discussion: rainwater treatment videos	(2) Comparative discussion
Week 4: Final reflection	10	Project presentation	
	10	Individual reflection	(4) Closing stage
	5	Co-evaluation	

The post-class tasks consisted of a co-evaluation and formulating the conclusions of the week's activities. A Miro-board was provided for each team as a co-evaluation tool, where students were asked to provide feedback to their peers in the other institution on their technical projects. The board was divided into 4 sections: (1) What was good? (2) What could be improved? (3) Ideas, and (4) Actors. Section 1 (What was good?) was used to acknowledge the strengths of the other university's team project work, section 2 (What could be improved?) aimed to identify possible shortcomings in the other university's project work, section 3 (Ideas) was intended to elicit proposals of project improvements or other ideas from any student to any team, and the final section 4 (Actors) was meant to provide a space where the team whose project was being evaluated could comment and respond to the feedback.

During the last COIL session, each intra-university team presented their final project design to their counterpart team in the mixed group. Each instructor observed half of the presentations at least partially. After the session, students were asked to complete a survey as part of the last COIL stage (reflection). We opted for a survey rather than a group reflection to give the students

privacy and time to reflect on the activity–they had a week to return the survey–without falling to peer pressure and/or group think.

Post-implementation

After the COIL experience was over, the instructors met with the International Collaboration Office facilitator at Tecnológico de Monterrey to share our reflections on the experience, based on comments from the students, our own observations, and survey responses. The instructors met twice after this meeting to discuss changes and improvements for a second implementation of the COIL experience in our courses.

Evaluation and feedback

Students received feedback from the instructors every week. The feedback was delivered in writing through their Google Documents, and it covered the content and whether the week's goal was achieved or not. Students had the opportunity to edit and improve their projects before the final delivery. As mentioned previously, a Miro board was used for peer co-evaluation and advancement assessment. The board was also reviewed weekly by the instructors to keep track of any possible internal conflicts or lags in the teams' progress. The COIL experience constituted 10% of the final grade in the respective courses. The weight given to each activity is listed in Table 1 above.

Student feedback on the COIL experience was provided through the final survey conducted as part of the last COIL stage above (Table 2). The survey consisted of a series of twelve questions, including Likert-scale, multiple choice, and open questions applied through Google Forms.

Table 2. Questions included in the COIL experience student feedback survey.

Question	**Format**
In the US, everybody has a constant supply of safe drinking water	Likert scale, 1-5, completely disagree to completely agree
From the previous statement, this is something that I:	Multiple choice: – Always knew – Learned before the COIL experience as part of the course – Learned as part of the COIL experience
Water issues in Mexico are very different from water issues in the US	Likert scale, 1-5, completely disagree to completely agree
From the previous statement, this is something that I:	Multiple choice: – Always knew – Learned before the COIL experience as part of the course – Learned as part of the COIL experience

Rainwater harvesting is a water availability solution for every region in Mexico and the US	Likert scale, 1-5, completely disagree to completely agree
From the previous statement, this is something that I:	Multiple choice: – Always knew – Learned before the COIL experience as part of the course – Learned as part of the COIL experience
Grade your ability to collaborate with international peers on a common project through virtual communication and learning platforms BEFORE this experience	Likert scale, 1-5, novice to expert
How confident do you feel about collaborating with international peers on a common project through virtual communication and learning platforms AFTER this experience	Likert scale, 1-5, the same to very confident
What similarities and differences did you find between the two classes (Rice University vs Tecnológico de Monterrey) and cultures?	Open question
Reflecting on all the videos that you watched, why is it important to learn about and work on the Sustainable Development Goals?	Open question
Reflecting on all the videos that you watched, how are you able as a person and a future professional to contribute to meeting SDG-6 and/or other SDGs?	Open question
Please provide any suggestions or comments to improve this activity, for future experiences	Open question

Findings

Based on observations by the instructors and student feedback, both directly and in writing, COIL participants had a wide range of experiences, where some teams worked well together, and others did not. The main factors behind these differences were:

1. Different levels of engagement, with some teams having good discussions whereas in others some students remained mostly silent and did not take part in the discussion.
2. Differences in project structure for students in both universities: students at Rice University were involved in a semester-long team project and the COIL activity (rainwater harvesting) was a subset of that project, whereas Tecnológico de Monterrey students were working in a one-month project limited to rainwater harvesting. These differences were due to the courses' requirements, syllabus, and nature.

3. Different team dynamics at Rice University and Tecnológico de Monterrey: Rice students were back to in-person learning and were able to work together in the classroom, whereas Tecnológico de Monterrey students were still in virtual learning mode and were not together with their teammates during the COIL sessions.

Student feedback

The final survey conducted during the last COIL stage was the main source of student feedback for the instructors. Out of the 38 participants in both universities, 30 students (79%) responded, of which 19 (63%) were from Rice University, and 11 (37%) from Tecnológico de Monterrey.

A majority (53%) of respondents reported learning about limitations to water accessibility issues in the US from the COIL experience. Students tended to see water issues in Mexico as different from the US (in a 1 to 5 Likert scale ranging from completely disagree to completely agree, the mean was 3.27), and the majority of the students (60%) reported learning this as part of COIL. Students (67%) also reported learning from the experience that rainwater harvesting is not a solution for every region in Mexico and the US.

The respondent's confidence in their ability to participate in international online collaboration improved after the COIL experience: Most students (23, 77%) graded their own ability to collaborate virtually with international peers as between novice and intermediate (1-5 Likert scale mean = 2.7) before the COIL experience. After the experience, most students (23, 77%) reported their confidence in collaborating with international peers in a virtual project being between intermediate and very high (1-5 Likert scale mean = 3.4), with 7 students (23%) reporting that it stayed the same or close to the same.

As part of the open comments section of the survey, the students were asked about the main takeaways from the COIL experience. Most of the students (25) thought the experience was positive and enriching, 4 labeled it as "negative" or "a distraction", and 1 student did not share their thoughts. In general, the students commented on learning about global water issues (e.g., "The videos that we watched as a preparation for each class and the discussions we had with students at [Tecnológico de Monterrey] have opened my eyes about where we stand now in water availability and pollution issues"). In addition, the three main themes brought up by the students were:

1. Communication: Students commented on the difficulties to communicate virtually, mentioning factors such as the language barrier, and lack of engagement in the breakout discussions by some students.
2. Similarities and differences between countries: Students commented on drinking water issues existing in both countries, even if the factors contributing to them and the solutions might be different. They also observed that people in both countries have similar goals and are working towards solutions, e.g., one student commented that "My main takeaway from this experience was that we have a lot in common with our global peers, because we

are all students with the goal of learning more and making an impact using our education."

3. Interaction between different cultures: Respondents reported the interaction as "enjoyable" or "nice", with some students noting that the interaction was minimal and could not express an opinion.

When students were asked to share their views on the similarities and differences between the two classes and cultures, 26 students mentioned at least one difference or similarity either between the classes or cultural issues, while 4 students mentioned that the experience did not provide them with information to comment on this question. The themes of the responses were mixed. Some students focused on the content and structure of the technical projects/course (6), others focused on the interactions with their peers (12), and the rest focused on differences on water supply and infrastructure of both countries (12).

The main difference between courses cited by the students was team organization (e.g., "The culture was different in that [Tecnológico de Monterrey] students didn't know each other at all, so they definitely had a different group dynamic than we did."). Some students commented on the differences between two countries (e.g., "One difference I [noticed] was our groups had slightly different approaches to water treatment because of the regions we lived in"), and two students from Tecnológico de Monterrey commented on the diversity and open mindedness of the students at Rice University: "[There] are more foreigners in their school there is a huge mix of culture and its [sic] interesting how they accept it" and "they welcome every opinion without judgment, open to new possibilities."

The similarities highlighted by the respondents were on the technical and water knowledge, project, and career goals of engineering students. Examples of the students' comments include:

- "Sometimes there was a language barrier when describing certain aspects of the water harvesting and treatment processes, so that was one cultural difference. Otherwise, it felt like we had a lot in common since we are studying similar things at university and are in the same age group."
- "The main similarity was how we both wanted a common goal of trying to help make water more accessible to people. I personally didn't find many differences between the two classes in regards to ideas or content we knew."
- "Both groups of students enjoyed engineering and building things."

All the students shared their views on the importance of working and contributing to the achievement of the SDGs, including SDG6, and how they can personally and professionally contribute. The general theme was that SDGs are important to improve and maintain global quality of life and reach equality. Some students identified some causes (e.g., inequality, even outside "poor-countries"), and necessary conditions to achieve the SDGs (e.g., multidisciplinary and communal work, international collaboration), and cited as reasons to learn about them the need to be informed about globally relevant issues in order to solve them. The general theme for their individual contributions was changing habits (e.g., using less water, reducing meat consumption), increasing awareness and volunteering or supporting organizations working on

water issues, and incorporating the SDGs to their professional practice, e.g., designing and implementing sustainable water treatment processes/technologies.

Instructor observations on logistics

In general, the Zoom sessions and breakout rooms worked smoothly, except for an internet interruption, when Rice University lost internet connection for several hours and affected one of the joint sessions.

The number of activities planned per joint session, as well as the number of virtual collaboration platforms used, were excessive. As an example, some teams used the Miro board every week, whereas others did not use it at all and did all their work on Google Docs. Even though on the first day of the collaboration, the instructions, steps, and structure of the COIL activities were explained to students, by listening in on the teams' breakrooms during the weekly discussions, the instructors realized that there was confusion over the Miro board. Although the instructions were repeated, no change was observed in the frequency of use of this tool.

Learning goals

The survey results and instructor observations indicate that the COIL experience contributed to the project's four student learning outcomes. For the first outcome, students reported an increase in their ability to understand, communicate, and work with peers from a different culture. Some participants commented that they recognized that communication across cultures takes effort, planning, and initiative. A few students from Tecnológico de Monterrey emphasized the importance of improving their language skills to facilitate interactions in a more diverse and international team.

The second learning goal was the students becoming familiar with organizational and academic aspects of academic cultures other than their own. Most of the students (26 out of 30) commented on at least one difference or similarity between the courses or cultural issues, with the main difference cited being team organization and culture. Students also mentioned the instructors having different teaching styles, that both courses had different contents and goals, and differences in the project extent, content, and structure in both universities.

As mentioned above, most students recognized that this experience increased their ability to collaborate with international peers on a common project through virtual communication and learning platforms. Finally, students reported learning about the importance of water quality and quantity from the COIL experience.

Lessons learned

Although the instructors deem this COIL experience to be useful as a pilot project, several changes are necessary to improve the experience in the future. The main changes proposed by the instructors and students are listed below in no particular order.

1. For the COIL experience to have a substantial synchronous component, the courses at Rice University and Tecnológico de Monterrey need to overlap better, e.g., start at a similar point in the semester, and have matching class times. Alternatively, an asynchronous experience could be developed based on the activities described above.
2. Reduce the number of virtual collaboration tools used, and the number of activities during the experience. The activities in this experience took longer than expected for the students to accomplish during the synchronous sessions.
3. Form consistent and inter-university teams. Having students in each university work on their projects independently and only engage with the other university's students to discuss their progress seemed to prevent a deeper sense of collaboration. In addition, team dynamics should be the same for all teams; during this experience, Rice University students were all together in the classroom and had known each other for several weeks, whereas Tecnológico de Monterrey students were all virtual and had not worked together at all. In a new version of this COIL experience, inter-university teams should be formed and work together as a single team in a common project. We also expect that students in both universities will be present in-person at their respective schools when the next iteration occurs.
4. Provide more opportunities for informal interaction between Rice University and Tecnológico de Monterrey students and encourage discussion of cultural differences and similarities between the two countries and universities.
5. Involve Teaching Assistants in the COIL experience to facilitate, coordinate and moderate discussion sessions in order to foster student participation in breakout rooms.
6. Emphasize to English-speaking students that their counterparts are participating in the COIL experience in a foreign language (even if the class itself is taught in English), and this may hinder their willingness to participate in discussions. Some of the American students were aware of this ("I thought it was very accommodating of the [Tecnológico de Monterrey] students that they communicated with us in English because I only know the one language.") but based on comments to one of the instructors, many of the English-speaking students had not considered this situation.
7. Plan for asynchronous collaboration for emergencies, such as the severe internet service interruption that occurred at Rice University.
8. Engage evaluation experts during the COIL experience planning, implementation, and evaluation to improve the measurement of learning outcomes.

Conclusion

Overall, and as a first iteration, the instructors concluded that the COIL experience, albeit challenging, was positive for students and instructors. Most students learned about the water topics discussed, increased their confidence in their ability to participate in international online

collaboration, deemed the COIL experience to be positive and enriching, and described their interactions with international peers as enjoyable. To the instructors, the experience and feedback from the students offered insight and improvements to be applied in the following iteration of this COIL experience, when we expect students in both universities will be present in-person at their respective schools.

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