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Humanitarian engineering, global sociotechnical competency, and student confidence: A comparison of in-person, virtual, and hybrid learning environments

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Humanitarian Engineering, Global Sociotechnical Competency, and Student Confidence: A Comparison of In-person, Virtual, and Hybrid Learning Environments

Abstract

The PIRE Responsible Mining, Resilient Communities (RMRC) project is a multi-country, interinstitutional, and interdisciplinary global research collaboration whose goal is to co-design socially responsible and sustainable gold mining practices with communities, engineers, and social scientists. This paper will investigate two key research questions. The first question considers how participating in the summer session influences students' global sociotechnical competency with the second question analyzing how the changes in sociotechnical competency impact the students' confidence in their engineering ability. The project hosted three intensive summer field sessions that each enrolled a different group of students. In 2019, the students conducted research in the field in Colombia while in 2020, the students completed the research completely virtual due to the Covid-19 pandemic. In 2021, the students participated in the project in a hybrid format with time split between the field and virtual work. To assess changes in students' learning and attitudes, we collected data from the students before and after the summer sessions in the form of interviews, surveys, and essays. The data will be analyzed to investigate whether the format of the summer session (in person, virtual, and hybrid) differently influenced students' global sociotechnical competency and their confidence as engineers. Other research has shown that service learning increases engineering students' confidence in their engineering ability. The data analyzed from this project describes how this may be context-specific. This paper will shed light on broader concerns in engineering education about if and how specific kinds of service learning can enhance students' global sociotechnical competency and their confidence as engineers.

Introduction

Our project is a multi-country, interinstitutional, and interdisciplinary research collaboration whose goal is to co-design socially responsible and sustainable artisanal and small-scale gold mining (ASGM) practices with communities, engineers, and social scientists in the United States, Colombia and Peru. A key component of this work is engineering education research that investigates how situated learning enhances undergraduate students' global sociotechnical competency, especially as it relates to their ability to define and solve problems with people from diverse disciplinary backgrounds and life experiences. In the summer of 2021, the COVID-19 pandemic was still causing disruptions in higher education, yet the availability of vaccines allowed students and faculty to gather in restricted in-person environments. This tension between restrictions and relaxations for in-person teaching and learning, and the impossibility of international travel for our undergraduate students, led us to develop and deliver a hybrid summer field session, described below. This paper will investigate two key research questions emerging from the session. The first question considers how participating in the 2021 hybrid summer session influenced students' global sociotechnical competency, and the second question

analyzes how the changes in sociotechnical competency impact the students' confidence in their engineering ability.

This was the third, two-week summer session we have hosted [1]. In 2019, all US students and faculty visited our counterparts in Colombia. In 2020, the COVID-19 pandemic meant that we were fully online, with each participant logging in individually from their work stations. In 2021, the session was hybrid. The U.S. students all met in person for two weeks, which allowed them to work together in one place while virtually engaging ASGM communities in problem definition, ideation and prototyping.This direct engagement using virtual platforms was an improvement over the 2020 session, in which students were primarily passive observers of the ideation process that took place between online moderators and ASGM miners.

The 2021 session, the focus of this paper, was held in two locations: first, in central Colorado, where the proximity of mining sites facilitated student visits and firsthand learning about mining, and second, in Colorado Springs, where students lived, learned and prototyped together in a secluded campus environment. In both locations, students connected virtually with ASGM miners and community members every afternoon. A total of 10 faculty, 10 graduate students, and 12 undergraduate students participated in the field session. For the purposes of this research, of the 12 participating undergraduates, only 7 completed the pre- and post- surveys and interviews analyzed in this paper. The other 5 undergraduates could not complete the surveys and interviews due to policies internal to their institution that prevented them from doing so. We also discuss in [1] how the time and energy demands of intensive sessions likely dampened students' desires to participate in the assessment activities.

The field session's learning outcomes included students being able to:

1. define the meaning of "sociotechnical" and apply this definition to ASGM;
2. explain how artifacts, processes, and systems involved in mining practices observed in the U.S. and Colombia are sociotechnical systems;
3. identify various ASGM stakeholders (miners, mining community members, partners, etc.) and the sources of knowledge (experiences, training, cultural awareness, education, etc.) possessed by them;
4. synthesize evidence from #2 & #3 to form a *preliminary* description of relevant sociotechnical systems found in respective mining communities;
5. collaborate with Colombian partners to identify new sociotechnical approaches to support the wellbeing of ASGM communities through engineering student design projects;
6. demonstrate how the potential sociotechnical solutions identified in #5 fit within the context of the larger sociotechnical model described in #4; and
7. build and validate a prototype of the sociotechnical solutions identified in #5 and solicit feedback from mining partners on potential design.

Daily activities included faculty presentations related to the goals, as well as previous graduate student research and undergraduate student design projects of our RMRC Project. The session began with an introduction to viewing engineering as a sociotechnical practice, with a focus on the intertwined political, material, and technological history of the region's mining industry. During the mornings of the first week, participants visited important mining sites in Central

Colorado, such as the Climax, Emmons, Akron, and Pitch mines. While these mines were different from those in Colombia, they nonetheless provided students the opportunity to see common challenges firsthand – such as tailings waste – and to compare and contrast the differing environmental, social, and technical dimensions of mining in the two places. The afternoon activities were virtual, facilitated by the organization RETOS (or "Challenges" in Spanish), which is a team of Colombian translators/mediators who identified the design projects and communities and also organized the interactions between them and our team. Students interacted with members of ASGM communities and learned about the specifically Colombian context of alluvial and hard rock gold mining, strategies for valuing local knowledge in the design and use of ASGM tools such as sluice boxes and a gold pans, and the process of co-design with communities. During the second week, and after having established virtual rapport with ASGM miners in Colombia, students virtually interviewed them in order to define problems associated with the design of gold pans and sluice boxes, engaged in ideation and prototyping, presented their prototypes to ASGM community members, and received feedback from them. The design projects were then integrated into a semester-long class at Institution 1. This paper focuses on the summer session only.

Service learning and student confidence

We are particularly interested in exploring whether and how the summer sessions influenced the students' global sociotechnical competency [1] and their confidence in their abilities as engineers. Engineering students' confidence in their technical and professional abilities is most often studied through the lens of self-efficacy [2], or an individual's belief in his or her capacity to execute behaviors necessary to produce specific performance attainments. Research in this field is expansive, using validated studies [3] to document correlations between students' positive self-efficacy and increases in their persistence, achievement, and interest in STEM [4]. Studies caution, however, that enhanced self-efficacy among women do not necessarily translate to greater feelings of inclusion, especially for women of color [5].

Of particular relevance to this study are investigations of the role that service learning can play in enhancing students' self-efficacy. Engineering students, especially women, recognize service learning as a source of technical and professional skill [6], [7], though other research cautions that students' confidence in their learning does not always predict their actual learning outcomes [8]. Comparing students from the same class who participated in a service learning design project and those who did not [7], found that the students participating in the service-learning projects showed "significantly higher gains in confidence in both technical and professional engineering skills." Though women in both types of projects experienced gains in their self-confidence, this increase was most dramatic for women students in the service learning projects, who showed an average increase of 81.6% in their technical confidence as engineers. The researchers highlight particular gains in students' confidence in understanding the needs of project stakeholders and identifying design needs, requirements, and constraints.

Our own prior research [1] showed mixed results for the influence of an intensive summer service learning experience for students' confidence. While students in both the in-person and virtual sessions showed moderate increases in their self-reported confidence in their ability as engineers, their scores for that question were significantly lower than the other questions. Scores on the question about confidence had average responses falling in the 3.0 to 4.0 range (out of 5), whereas almost all of the other questions had averages in the 4.0 to 5.0 range. As described below, we also asked students to report on their confidence in specific areas of practice, such as engaging in perspective taking, talking and working with people from backgrounds different from their own, and integrating the perspectives of stakeholders into their engineering designs, though we did not identify clear patterns of responses within or across the sessions.

Methods

Data Collection

For the field sessions over the course of the three summers, the same set of protocols were utilized to complete data collection of the research participants. Each summer, the students completed three assessment exercises both prior to the field session and following it. Completing these exercises after the summer session assisted in understanding the influence of the session on the student's sociotechnical competency and confidence.

To analyze the confidence in abilities of the participants, multiple questions were asked of the students in the form of a survey, before and after the field session. The survey included 25 questions, drawn from previously validated studies [1], that covered a broad range of topics. Each of the following questions involved insight into the students' confidence and self-efficacy:

Question 4: It is easy for me to see other people's points of view.
Question 5: I feel confident talking with the people who will be affected by my engineering design projects.
Question 7: I feel confident integrating perspectives from non-engineers into my engineering design projects.
Question 8: I feel confident working with engineering students from different backgrounds than my own.
Question 12: I am confident in my abilities as an engineer.
Question 14: I can make positive changes in communities through engineering.

Students also wrote essays responding to prompts that asked them to go through their process for identifying problems in the ASGM space and engaging stakeholders to solve them. The questions participants were considered were the following:

1. What do you think are the biggest challenges related to artisanal and small-scale gold mining (ASGM) in Andes, Colombia?
2. What do you think the miners in Andes would identify as the biggest challenges related to their work?
3. What should be the desired outcomes of interventions to make ASGM more sustainable in Andes? Prioritize them in a list.
4. How do you think miners in Andes would identify and prioritize the desired outcomes of interventions to make ASGM more sustainable?
5. Who are the key stakeholders related to ASGM in Andes? Create a list of how you would prioritize them in the process of co-design.
6. Provide one example of a "solution" for ASGM challenges that is appropriate for the local context of Andes. Explain why it is appropriate to this specific historical, cultural, economic, and physical context.

A one-on-one structured interview between the student and a member of the project faculty or staff helped provide greater depth and nuance to understanding the students' experiences. The interviews in the 2021 field session included an additional set of questions that analyzed the students' view on self-identity and feeling of belongingness in their communities. These questions could then be used to better understand the participant's self-efficacy:

1. Are there certain aspects of your university that play a role in how you see yourself as a successful engineer?
2. Are there any aspects of your university that help you connect your educational experiences to your future career?
3. Do you feel that the faculty and other academic staff play a role in how you see yourself as a successful engineer?
4. How have staff or other aspects of your university make you feel undermined or have caused you to question yourself about being successful in engineering?
5. What are the top three characteristics of a program that solidifies that you belong in engineering?
6. What is an example of an experience in engineering that made you feel like you belonged in the nature of the profession?
7. Can you think of an example in engineering that made you feel you didn't belong in the nature of the profession?

Data Analysis

We previously analyzed shifts in the 2019 and 2020 students' global sociotechnical competency in [1]. For this paper, we update the analysis of global sociotechnical competency to include the

2021 students in the hybrid session. As this is our first analysis of shifts in confidence, we analyze all three sessions for those questions.

To analyze the surveys, participants from all three field sessions were examined. For each question, averages were taken for each participant, as well as averages for all of the pre and post survey answers. The table below displays the average pre and post survey scores for 6 questions that correlate with confidence and self-efficacy.

The writing exercises assisted in providing insight on the participants' sociotechnical competency before and after working with stakeholders in the summer sessions. Analyzing the essays over the summer sessions for 2019 and 2020 displayed clear results in the participants' understanding of what components are needed for a sufficient engineering solution. 2021 was done using the same protocol from previous years of highlighting the essays as described in our previous publication. The essays were analyzed for understanding the relationship between social dimensions and technical components.

The interviews were transcribed and analyzed for two different components for the 2021 field session. Similar to previous years, the interviews were examined by highlighting any potential changes between the pre and post interviews for every participating student. The interviews from 2021 included an additional set of questions regarding belongingness and the responses to these questions contained insight on information about the students' confidence. In addition, there were impacts to the changes in confidence and self-efficacy, which were also highlighted. The interviews were then analyzed for changes in sociotechnical competency. This was done through examining changes in wording and description of proposed sociotechnical work.

Potential Limitations

For the 2021 summer field session, there were limitations that would be important to recognize and analyze to better understand the data. Such as in previous summer sessions, there was a small number of students who participated in the research project. For the 2021 field session, there were eight students that participated in the interviews, essays, and surveys. However, of these eight students, not every student completed both a pre and post of one of the forms of data collection. There were several students from the field session who did not provide informed consent to participate in the data collection which resulted in not a complete data set to look at. The number of students who provided data in the summer sessions for 2019 and 2020 can be found in our previous publication [1].

In addition to a small number of students who gave informed consent and full participation, a small amount of the questions asked in the surveys and interviews could be used to analyze the students' confidence in their abilities and self-efficacy. There is always a chance that questions

asked could be interpreted by students in varied ways, so follow up work should ask students more open-ended questions about confidence.

Results

Sociotechnical Competency

We understand global sociotechnical competency as including the elements of sociotechnical coordination, understanding and negotiating engineering and relevant national and local cultures, navigating ethics and regulations, and socially responsible engineering which are fully described in [1]. This concept of sociotechnical competency synthesizes multiple scholarly perspectives on engineering education [9].

Participant Sociotechnical Competency Quotes		
Participant	**Pre**	**Post**
Participant 31	"This would be appropriate because it would help the people in those communities, and it will protect their history." "All of these stakeholders have a vital part in the solution for the ASGM mine in the Andes Columbia."	"The solutions are solutions that may work, or they may not work, but these solutions must be tailored to their surroundings, that is where the co-design aspect comes in … "
Participant 35	"... We don't consider how the community is going to be impacted by that …"	"... I was working in a more abstract knowledge, like I didn't feel that there was a way to apply that knowledge. And now, like I think, even those technical problems we always have to consider the social part …" "... like it's either engineering or social aspect, but like during the project, I realized that we work a lot on connecting both and how they compliment each other, and both are really important to actually find good results."

Participant 36	"... in order to begin to understand the desired outcomes … we need a full or better understanding of all aspects of ASGM practices, including the cultural, economic, social, and environmental implications."	"Be aware that if we're working with communities, it's important to engage with them" "... we have some sort of technical knowledge we can use to better their processes … we attain that through social interactions …"

Table 1: Example quotes from student essays displaying sociotechnical competency

As shown in Table 1, several participants from the 2021 session showed a positive progression in their sociotechnical competency. As Participant 36 described in their pre-essay, they already had an understanding of all of the components that were necessary for the project. Participant 35 was the best example from the 2021 summer session at displaying an increase in sociotechnical competency because they were able to describe the changes that need to be made in engineering solutions after completing research.

The improvements we saw in the 2021 session were fewer in number than the 2019 and 2020 students [1]. We suspect that this is because many of the students already demonstrated a deep understanding of how social dimensions and technical components are both necessary for engineering solutions. One of the limitations of the project made a more thorough analysis difficult: not all participants completed a pre and post essay assessment, making it difficult to display changes in pre versus post-session understanding compared to previous years.

Confidence in Abilities

Participant Confidence and Self-Efficacy Quotes		
Participant	**Pre**	**Post**
Participant 26	"... my honors professors … like all English professors … make me feel like I'm a successful engineer more than the engineering professors do … they are very supportive and willing to listen and to give advice …"	"... I also wanted to hear more about the daily life of a miner … really wanted to see the full picture … maybe this is something that I can kind of do both, I can be that sociotechnical professional …"
Participant 27	"I would say I am worthy of becoming an engineer … you just have to find out what you're good at and as long as you can get by, it'll be ok."	"... I sort of feel like I have a little bit of Imposter Syndrome because I don't have any technical experiences …"
Participant 33	"... it seemed like there was more important stuff like passing a student and stuff like teaching the material and making sure, like a student learns, as if there was more of a focus on just passing the class."	"I think it made me be more specific and the type of engineering I want to do. And just like set me in a direction that makes sense, like found a direction to go."
Participant 35	"... it's mainly related with gender … know having support of boys, like they might think sometimes that you are not as capable as them. And sometimes that makes you think that probably this is not your place or you really want to do many things, but they kind of like, stop you."	"... engineering is the right path for me …" "So it makes you think that it doesn't matter what kind of personality you have or where you go to study like you can always work together to have a better result."

Table 2: Example quotes from student essays displaying changes in self-efficacy

The pre and post quotes above describe how students view their self-confidence in engineering, including their social skills. In addition, Table 2 clearly describes some of the external impacts students experience that influence their self-efficacy. For example, college professors and faculty assist in providing different mindsets and perspectives that help shape student's opinions and knowledge, as seen in Participant 26's quote above. Staff provide advice and teach lessons that

engineering students can take with them into the field. Not only do professionals have an influence on confidence, but so do peers as well. Participant 35 discussed how their gender plays a role in their confidence when working with others. While some experiences may have been negative, student participants believe that making connections with others in their post-secondary education will make them better engineers in their future careers.

A frequent comment participants made discussed how engineering courses somewhat train students to look for the "correct answer" when determining solutions for an engineering problem. After completing the summer session, students were able to recognize that engineering solutions involve more than one correct answer and have several components that need to be considered. Another pattern found in the interview responses was the recognition that it will take time and experience to gain confidence in engineering abilities.

The survey results for the questions about confidence are varied. One thing to note in Table 3 is Question 12, which asked the students' confidence in their engineering ability. As seen in the averages, confidence increased after students completed the research session each of the three years. However, one thing to note is how the averages for Question 12 were almost one whole point lower than the averages for the other questions displayed above which raises the question, why do students not feel confident in their engineering ability? Other than Question 12, there are cases where certain aspects of the students' self-efficacy decreased, such as with empathy and perspective taking. There were no instances where the decrease was very large, or greater than 0.5. The questions cover multiple characteristics of self-efficacy such as confidence in working with others and creating change from obtained knowledge.

		Averages	Question 4	
Empathy & perspective taking	2019	Pre	4.40	
		Post	4.20	
	2020	Pre	4.43	
		Post	4.00	
	2021	Pre	4.14	
		Post	4.00	
			Question 5	Question 7
Integrating social concerns	2019	Pre	4.40	4.20
		Post	4.40	4.40
	2020	Pre	4.00	4.71
		Post	4.00	4.40
	2021	Pre	4.29	4.00
		Post	4.29	4.71
			Question 8	
Working with people from different backgrounds	2019	Pre	4.50	
		Post	4.80	
	2020	Pre	4.29	
		Post	4.40	
	2021	Pre	4.43	
		Post	4.29	
			Question 12	
Self-efficacy	2019	Pre	3.40	
		Post	3.60	
	2020	Pre	3.29	
		Post	3.80	
	2021	Pre	3.29	
		Post	3.57	
			Question 14	
Views of engineering	2019	Pre	4.40	
		Post	4.00	
	2020	Pre	4.14	
		Post	4.40	
	2021	Pre	4.71	
		Post	4.71	

Table 3: Averages from the confidence questions on the student surveys

While the average numbers in the survey were low for Question 12, and for some of the other questions, the quotes shown in the table above provide a different interpretation. The participants

from the 2021 summer session explicitly stated they felt more confident in their engineering abilities and capabilities of creating change in their communities. This is why it is very important to be deliberate about which method of data collection to use. When conducting an interview, it is easier to have a better understanding of how the student is approaching the question because follow up questions can be asked, whereas we are less certain with how students interpreted the survey questions. This is beneficial to know for future data collection methods.

Conclusion

It is intriguing that when students are asked to rate their self confidence in engineering, they provide scores that were significantly lower than their confidence in particular skills, such as integrating social concerns into a design or working with people from different backgrounds. Their qualitative interview responses, however, tell a different story, underscoring the value of mixed method research. From our research, we are particularly concerned that our students lose confidence in their engineering abilities when their views are broadened, either by interacting with communities that have non-engineering yet expert knowledge or by being exposed to engineering as a sociotechnical endeavor. We suspect that the process of actually interacting with and learning from community members – rather than simply expressing a need or desire to do so – tempers their confidence in practicing empathy and perspective taking by serving as a reminder of how difficult those activities are in practice. More research needs to be done to understand the complex relationship between broadening students' views and their loss of confidence.

There are several routes future research and data collection could take. It would be beneficial to follow up with the participants from the 2021 summer session to see how their confidence and self-efficacy has shifted long-term after completing the RMRC project. This will be relevant for how training of the research participants is completed. While the present study was conducted with a handful of students, allowing us in-depth interviewing, essay writing and surveying with them, if the research group is expanded, data analysis methods will need to be adjusted to increase efficiency.

While the present study was conducted within a specific project and institutional context, we hope that this study inspires others in other community-engagement related activities (e.g., international and domestic community projects, service learning courses, community-focused study abroad, virtual courses, etc) to explore the relationship between situated learning, global socio technical competency, and student confidence.

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