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Why do I have to know this? Engineering in a Globalized Society

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WHY DO I HAVE TO KNOW THIS? ENGINEERING IN A GLOBALIZED SOCIETY

by

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Abstract

Through a pilot comparative study, this thesis examines the problem-solving of chemical engineering students and chemical engineering faculty. Specifically, the thesis examines the extent to which individuals include global factors (cultural, social, environmental, and economic) into their engineering solutions as specified by ABET. Several hypotheses were investigated in this pilot study: (i) having a study abroad experience would increase the likelihood that participants included the global factors of interest, (ii) the type (PUI, Research Intensive, Unique) of institution students attended would impact how individuals approached the problem, (iii) students with similar career aspirations would approach the problems similarly, (iv) having industry experience would increase the likelihood of including the global factors of interest, (v) having international collaborators or traveling for work would increase the likelihood that participants included the global factors of interest. Additionally, students and faculty with similar experiences were compared to see if they approached problem-solving similarly based on the shared experience. While the sample size collected was small and no generalizable conclusions can be made, the work can be expanded upon. The methodology employed, due to its originality, requires further iteration to improve its validity. This thesis lays the groundwork for future research in engineering education as researchers look at ways to pedagogically produce more globally-minded engineers.

Introduction

Globalization has affected every aspect of life, from the economy and manufacturing to societal trends and politics. While globalization and education are not often thought to be interconnected, globalization is shaping engineering education. Organizations like ABET are challenging and molding academic institutions to produce graduates that take a global approach to problem-solving as a response to an increasingly globalized society.

This thesis paper explores how often chemical engineering students and faculty incorporate global-social problem-solving into their solutions. Chemical engineers impact almost every industry worldwide; for example, chemical engineers maintain oil rigs, manufacture life-saving drugs, and work on delivering clean water. As chemical engineers touch such a wide-array of global industries, it is extremely important that they are able to incorporate global-social problem-solving into their work. ABET's current student outcomes it lists, student outcome 2 states that students must have "an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors" (ABET, 2017). This outcome was approved by the Engineering Area Delegation in 2017 and went into effect during the 2019-2020 school year. A similar outcome had previously been in place that also required students to achieve global competency. This is the only criterion that refers to requiring that graduates are able to produce solutions that consider global factors like economic, environmental, cultural, and social factors.

Purpose and Research Questions

As our society becomes increasingly connected, engineers must be prepared to solve problems at a global scale and take non-technical aspects into consideration in their problem-solving. The purpose of this honors thesis research is to pilot a comparative study of engineering students and engineering faculty approaches when solving problems within a global context. In this study, I specifically compare two populations, undergraduate seniors and engineering faculty, across different types of institutions (Bucknell University, Kansas State University, Ohio University, University of Southern California, University of Oklahoma, University of Illinois Urbana-Champaign, University of Maine, University of California Los Angeles, Colorado School of Mines, University of Iowa, Missouri University of Science and Technology, University of Idaho, Oregon State University, Ohio State University, Case Western Reserve University, Clarkson University, University of Mississippi, University of Toledo, and Louisiana State University) in an effort to answer the following research questions:

1. Does having a study abroad experience change how individuals approach their problem-solving?
2. Does the type (PUI, Research Intensive, Unique) of institution students attend impact their approach to problem-solving?
3. Does the career aspiration of students impact how they approach problem-solving?
4. Does having industry experience impact how faculty approach problem-solving?
5. Does having international collaborators or traveling for work impact how faculty approach problem-solving?

Implications of Work

Comparing the results from the student and faculty population provides insight into whether the faculty population's practice is aligned with their students as well as what ABET requires. A discrepancy with what ABET requires and what faculty practice may imply that students will not achieve the ABET outcome.

Furthermore, this work could be used to better chemical engineering programs. If a population, Research Intensive Institution or Primarily Undergraduate Institution, for example, performs better than other populations then it would suggest that other programs may benefit from making changes to better meet student outcomes. Additionally, if students that study abroad on average perform better than students that do not study abroad then programs should emphasize study abroad experiences.

This pilot study also lays out the groundwork for future research for exploring how global competency is achieved. Additionally, this study provides a methodology that can be expanded upon for exploring the qualitative and ill-defined factors included in the ABET outcome (global, economic, environmental, cultural, and social factors) being explored.

Background and Literature Review

This section outlines the background needed to understand why globalization and engineering education are so intertwined. Additionally, it explains how ABET developed its outcomes to address the need to produce globally-minded students. The last subsection consists of a literature review on various styles of interviewing as background for the research methods.

Globalization and Engineering

In response to the importance of addressing an increasingly global society, higher education graduates are expected to understand how globalization affects their respective fields. The American Council on Education, in 2000, wrote:

> America's future depends upon our ability to develop a citizen base that is globally competent. The nation's place in the world will be determined by our society-whether it is internationally competent, comfortable, and confident. Will our citizens be competent in international affairs, comfortable with cultural diversity at home and abroad, and confident of their ability to cope with the uncertainties of a new age and a different world?

The Council emphasizes that a successful and prosperous nation will need its graduates to be internationally competent and able to understand problems beyond a nationalistic mindset. The need for graduates to be globally competent reflects protecting national security and national interest and maintaining the "nation's place in the world". The Council's call for developing globally competent individuals, while 20 years ago, is reflected in ABETs outcome for producing globally competent engineers.

Engineering in the United States has had to adapt to a changing economic and manufacturing landscape in this increasingly globalized society. Products are typically no longer made and subsequently strictly kept in one country. Products manufactured by engineers in the United States are often exported, which requires adherence to different federal standards, or utilize products from around the world. For example, Apple's iPhone supply chain includes products manufactured all over the globe including China, Japan, and Switzerland (Shobhit, 2019).

Engineers may also work at a company that outsources or insources their engineering expertise to plants in other countries.

Globalization and engineering are not strictly tied to manufacturing, but also to engineering design. Engineers design for a diverse group, both domestic and internationally, and regional competence can also be an issue within the United States. For example, understanding the problems of a rural town in Arizona is increasingly difficult if an engineer's experiences are limited New York City. Education is a way to increase global competence and ABET has taken initiative by requiring its accredited institutions to produce globally competent engineers.

ABET

Engineering programs are required to meet Engineering Criteria put in place by ABET (formerly the Accreditation Board for Engineering & Technology) in order to be accredited and recognized as quality (ABET, 2019). The 2019 outcome of interest ABET requires of its accredited programs is:

> 2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

This is outcome 2 in the second set of outcomes; the entire set of outcomes can be found in Appendix A. These outcomes were approved by the Engineering Area Delegation in 2017 and went into effect during the 2019-2020 academic year. The previous version of this ABET outcome required students to be able to have "The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context," (ABET, 2017). This skill is often referred to as a professional skill (Shuman et. al, 2005) and was

developed as a response to old accreditation standards being too rigid and stifling innovation (Prados, 1997). Professional skills do not just include social skills or leadership ability, but, for engineers, also the tacit knowledge of how one's work impacts a globalized society (Oberst and Jones, 2005). For instance, Shuman et. al write,

> "Engineers must understand that in a global context, engineering solutions, whether consumer products or unintended consequences such as resource exhaustion and environmental pollution, increasingly cross or transcend international boundaries. Global sustainability, for example, may eventually outweigh technical and other aspects of manufacturing," (2005).

While understanding engineering solutions in a globalized context is a required ABET outcome, in a survey given to engineering graduates, this outcome was perceived as the least important by in graduates' current work (Passow, 2012). Passow's study found that Computer Science graduates in particular ranked this outcome the least important (2012).

Outcome 2 is also considered to be the hardest to teach in engineering education (Okamoto and Rhee, 2005). A global perspective necessitates both a historical and societal perspective, which requires many liberal arts electives for students to achieve (Okamoto and Rhee, 2005). Additionally, most institutions do not address it until students partake in a program's culminating capstone course (Biney, 2007).

Educational institutions are charged with producing students that are ready for the workplace and are sought after by employers. Graduates must be prepared to work in a forever-changing work-

landscape–they must be able to adapt. In order to promote educational innovation, ABET allows for flexibility within their accreditation process (Lattuca et al., 2006). Shuman et al. call the second set of outcomes, first published in 2000, soft skills because they are non-technical, but necessary to produce a "complete" engineer (2005). The so-called soft skills are as follows:

1. An ability to function on multi-disciplinary teams
2. An understanding of professional and ethical responsibility
3. An ability to communicate effectively
4. The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
5. A recognition of the need for, and an ability to engage in lifelong learning
6. A knowledge of contemporary issues

The requirement of institutions to meet these soft-skills criteria was partially driven by employers who believed that graduates, while competent in their engineering field, did not have the professional skills to be successful in the workplace (Lattuca et al., 2006).
These skills are extremely hard to teach, in part because faculty are not formally trained in the soft skills (Grose, 2004).

Education and Globalization

In higher education, the term internationalism is often used in lieu of globalization. However, internationalism also lacks a universally accepted meaning. While internationalism and globalization are very similar, internationalism asserts the importance of collaboration (Marginson and Van Der Wende, 2006). One model of internationalism, the liberal model, recognizes the obligation for developed countries to teach students from developing countries (Tillet and Lesser, 1992). The liberal model also believes that by having students from a wide

array of backgrounds and international students, faculty and other students stand to intellectually benefit (Tillet and Lesser, 1992). That is, forming a diverse community will benefit students from a non-diverse background as well as students from a diverse background. Many universities currently emphasize the importance of developing students' international perspective. Bucknell University's, a primarily undergraduate institution in Pennsylvania, mission statement includes the following:

> "Bucknell fosters a residential, co-curricular environment in which students develop intellectual maturity, personal conviction and strength of character, informed by a deep understanding of different cultures and diverse perspectives," (2019).

In order to develop an international perspective in higher education, cultural or international connections must be present in teaching and must be made by an institution's administrators (De Wit, 1999). The National Association of State Universities and Land-Grant Colleges (NASULGC) created a task force to enhance both students' global competency as well as international education. In 2004, NASULGC wrote that a globally competent institution has the following:

1. Has internationalization as an integral part of its vision, mission, and strategic plan.
2. Has strong commitments and financial support from top university administrators.
3. Integrates international perspectives into all curricula and co-curricular programs.
4. Promotes, encourages, values, and rewards faculty and staff involvement in international activities.
5. Integrates international perspectives into appropriate research and outreach programs.

6. Has a campus culture that values and encourages international aspects in all programs, among faculty and students, and in campus life.

As globalization and internationalism became more apparent organizations like NASULGC investigated how to adapt its institutions to best prepare students and faculty for a continually changing landscape. In 1997, the Organisation for Economic Co-operation and Development (OECD) noted that it was becoming more and more important for internationalism to be present in education (OECD, 1997). International competency is also believed to be integral for the future competitiveness and security of the United States. NAFSA, the world's largest nonprofit association that is committed to international education and exchange, writes, "The challenges of the new millennium are unquestionably global in nature. This reality imposes a new and urgent demand on Americans, one this country has been all too quick to ignore: international knowledge and skills are imperative for the future security and competitiveness of the United States," (2003).

Global competency is the term that many organizations believe must be achieved by individuals if they are to be properly equipped to enter a competitive work landscape. Additionally, the onus is on higher education institutions to create globally competent individuals (Brunstein, 2007). Global competency, according to the PISA assessment is defined as:

> "The capacity to examine local, global and intercultural issues, to understand and appreciate the perspectives and worldviews of others, to engage in open, appropriate and effective interactions with people from different cultures, and to act for collective well-being and sustainable development," (2018).

While there are many views on internationalization and how to achieve global competency, it is evident that as society becomes more and more interconnected institutions must continually adapt to best prepare its students for a changing globalized society.

Qualitative Research Interviews: Frameworks and Styles

Research interviews are broadly used in ethnographic research and when conducting field studies (Qu and Dumay, 2011). Ethnography is defined as, "The recording and analysis of a culture or society, usually based on participant-observation and resulting in a written account of a people, place or institution," (Simpson and Coleman, 2017). Alvesson outlines three frameworks for the research interview methodology: neopositivism, romanticism, and localism (2003). Table 1 below shows a summary of Alvesson's outlined frameworks as adapted by Qu and Dumay.

Table 1: *Three interview frameworks as outlined by Alvesson (2003).*

Position	Interview	Interviewer	Interviewee	Accounts
Neopositivism	As a tool for collecting data	As a capable researcher to trigger honest response	As a truth teller	As objective data and knowledge transfer
Romanticism	As a human encounter between the interviewer and the interviewee	As an empathetic listener to explore the inner world of the interviewee	As a participant to reveal real life experiences and complex social reality	As a pipeline of knowledge mirroring interior and exterior reality leading to in depth shared understanding
Localism	As an empirical situation that can be studied	As people who are involved in the production of answers through complex interpersonal interaction	As people who are not reporting external events but producing situated accounts	As situated accounts that must be understood in their own social context

Source: Qu and Dumay (2011) who adapted Alvesson's (2003) work.

Neopositivism seeks to minimize bias. The researcher must remain neutral when interviewing participants (Miller and Glassner, 1997). The interviewer must act as if there is no context, or that context does not impact, the asked questions or the participants' answers (Gubrium and Holstein, 2001). Though this technique is considered to be objective it is not without criticism. Because of how the interview is conducted there lacks trust and control over how a participant answers questions (Morgan, 1997). In order to remedy the lack of trust and control, some researchers will conduct repeat interviews with participants (Morgan, 1997).

The romantic framework takes a humanistic approach. It seeks to unveil an interview participants' experiences and beliefs by building trust through conversation between the interviewer and interviewee (Qu and Dumay, 2011). The romanticist framework, unlike neopositivism, emphasizes the necessity for there to be interaction between the researcher and the participant (Alvesson, 2003). The researcher and participant are equals in this approach and because of this the likelihood of emotional responses is higher, which can present a more realistic picture depending on the research question (Fontana and Frey, 1998).

A localist framework looks at understanding an interview within a social context (Qu and Dumay, 2011). Hammersley, on localism, writes, "Social phenomena do not exist independently of people's understanding of them, and that those understandings play a crucial generative role," (2007). Localism views interviews as empirical and that the participant's responses need to be delved into deeply as they are individual accounts or experiences (Qu and Dumay, 2011). A localist framework is often thought to be useful to examine "complex social or organizational phenomena" (Qu and Dumay, 2011).

Interview structure is incredibly important as it greatly effects responses. Within an interview there are three methods for conducting an interview: structured, semi-structured, and unstructured (Alvesson, 2003).

In structured interviews, all participants are asked the same pre-determined questions (Qu and Dumay, 2011). Structured interviews are also referred to as standardized interviews (Berg, 1998). Because these interviews are extremely structured the types of responses given by

participants are fairly limited, which allows for easy data analysis (Qu and Dumay, 2011). Most structured interviews require the interviewer to read from a script, which minimizes any researcher bias as the researcher will most likely not elicit any responses (verbal or non-verbal) that may add any bias into the data collection (Qu and Dumay, 2011). Questions are developed by individuals that may be expecting or hoping for specific results, which allows for implicit bias to be inserted into the research design but following standardized procedures can minimize this and reduce the likelihood of bias being present in the study (Qu and Dumay, 2011). Localists and romanticists argue that this standardized approach comes at the cost of losing detail and flexibility as well as the ability to adapt the study to the wide variety of backgrounds held by many participants (Doyle, 2004). Neopositivism argues that researchers are adept individuals seeking honest responses and that the participants are going to tell the truth (Qu and Dumay, 2011). This requires the assumption that the asked questions are able to divulge all of the information that the crafted question was meant to (Qu and Dumay, 2011).

Unstructured interviews are also known as informal interviews, which are open-ended in nature (Qu and Dumay, 2011). In an unstructured interview, the participant is meant to be relaxed and feel unassessed, which is done through a lack of perceived structure (Hannabuss, 1996). Interviewers should be under the assumption that they do not know all of the questions necessary to uncover the answer to their research question (Qu and Dumay, 2011). The goal of not having structured questions is to not put any ideas or thoughts into the participants head by potentially subliminally triggering a response in hopes to find their unique perspective instead of potentially hearing what the interviewer wants to hear (Greene, 1998). Qu and Dumay (2011) write, "Therefore, in an unstructured interview, the interviewer must develop, adapt and generate

follow-up questions reflecting the central purpose of the research." In order to build the trust between the researcher and the participants, unstructured interviews can take time as trust needs to be developed through conversation. However, as trust is developed many researchers, following the romanticist framework, believe that an unstructured interview contains very little bias as the participant does not hide information from the interviewer because they trust them (Alvesson and Deetz, 2000).

As the name implies, semi-structured interviews take components from both unstructured and structured interviews. Semi-structured interviews are the most practiced interview style within qualitative research (Alvesson and Deetz, 2000). Semi-structured interviews include prepared questions like structured interviews do but allow the interviewer to gather more information through ad-libbed probes or further inquiry. The prepared questions are meant to guide the interview to uncover various research questions and themes while the additional inquiries can provide more detail and can allow for more detailed data collection. Of the three styles of interviewing, semi-structured are thought to have the highest efficacy and are the easiest way to gather data (Kvale and Brinkmann, 2009). This is because it allows the researcher to gain the most complete response from a participant as they can probe further into a participants thoughts, but it also allows the participants to explain their thoughts on their own-terms as it is not extremely structured (Qu and Dumay, 2011). The localism framework believes that semi-structured interviews unmask the research participants perspective (Qu and Dumay, 2011). Semi-structured interviews are not without critique, however. Because semi-structured interviews are partially driven by the interviewers' inquiries, different responses can be elicited depending on the mannerisms of the interview or even the interviewer's identity. Thus, a critique of semi-

structured interviews is that the interview produces information, which should be recognized as being gathered through the framework of intersectionality. This is because the gender, race, ethnicity, economic-status, and socio-status of the interviewer impacts the responses that may be collected (Denzin and Lincoln, 1998).

While there are three different frameworks and interviewing styles there is not a style that is colloquially agreed upon as the best. As there is not an agreed-upon style that leads to an ideal dataset, careful planning and mapping must be done to utilize interviewing as a qualitative research method. However, there are techniques and principles to follow that are recommended to increase the likelihood of good data collection as well as to improve the overall interviewing experience. Schensul et al. (1999) outlines three principles to ensure a successful interview. The principles are as follows:

1. Maintaining the flow of the interviewee's story
2. Maintaining a positive relationship with the interviewee
3. Avoiding interviewer bias

Hannabuss (1999) also describes skill sets that can ensure a successful and productive interview. They are as follows:

1. Ability to establish rapport with the participant
2. Able to keep the discussion going
3. Ability to avoid questions that diminishes or slows the conversation
4. Know how to refocus a discussion
5. Able to be judgement-free

The following table, Table 2, is adapted by Qu and Dumay (2011) from Kvale (1996) and describes types of questions that may be deployed by interviewers, their purpose, and various examples.

Table 2: *Types of questions, their purpose, and examples.*

Types of Questions	Purpose of questions	Some Examples
1. Introducing questions	To kick start the conversation and move to the main interview	"Can you tell me about [...]?" "Do you remember an occasion when [...]?" "What happened in the episode mentioned?"
2. Follow-up questions	To direct questioning to what has just been said	Nodding, "mm", Repeating significant words
3. Probing questions	To draw out more complete narratives	"Could you say something more about that?" "Can you give a more detailed description of what happened?" "Do you have further examples of this?"
4. Specifying questions	To develop more precise descriptions from general statements	"What did you think then?" "What did you actually do when you felt mounting anxiety?" "How did your body react?"
5. Direct questions	To elicit direct responses	"Have you ever received money for good grades?" "When you mention competition, do you then think of a sportsmanlike or a destructive competition?"
6. Indirect questions	To pose projective questions	"How do you believe other pupils regard the competition of grades?"

7. Structuring questions	To refer to the use of key questions to finish off one part of the interview and open up another, or to indicate when a theme is exhausted by breaking off long irrelevant answers	"I would now like to introduce another topic [...]"
8. Silence	To allow pauses, so that the interviewees have ample time to associate and reflect, and break the silence themselves with significant information	
9. Interpreting questions	Similar to some forms of probing questions, to rephrase an interviewee's answer to clarify and interpret rather than to explore new information	"You then mean that [... .]?" "Is it correct that you feel that [...]?" "Does the expression [...] cover what you have just expressed?"
10. Throw away questions	To serve a variety of purposes, i.e. to relax the subject when sensitive areas have been breached	"Oh, I forgot to ask you [...]"

Source: Qu and Dumay (2011) who adapted Kvale's (1996) work.

Methodology

The intended method for this study was a survey, which was going to be follow-up by interviews. This section includes changes that were made from the proposed thesis as well as the methodology, for both data collection and analysis, for the survey. Unfortunately, the interviews were not able to take place because of extenuating circumstances (COVID-19), but the analysis methodology as well as the interview guide that were to be given to interviewers is provided.

Changes from Thesis Proposal

The final study design includes several changes from the originally proposed work. LIWC, a linguistic software, was abandoned in favor of emergent thematic analysis as the former methodology requires in-depth knowledge of linguistics and the topics of interest are linguistically variable. Emergent thematic analysis is better aligned with the vague and variable nature of the topic of interest. Additionally, the sample population has been narrowed from engineering in general to strictly individuals from ABET-accredited chemical engineering programs. Survey questions have been crafted to better suit thematic analysis in consultation with Dr. Elizabeth Reddy from the Colorado School of Mines. Dr. Reddy is an anthropologist that specializes in engineering education and how experts respond to risks and communicate about risk within their jobs.

Sample (Population of Interest)

A survey disseminated to compare two main populations: (i) senior undergraduate chemical engineering students and (ii) engineering faculty. Senior-year students were chosen because capstone courses are the most likely time to capture program outcomes (Rogers, 2007). The population includes three institution-type based subsets: (i) Primarily Undergraduate Institutions (e.g., Bucknell), (ii) Research Intensive Institutions (Large State Schools), and (iii) Unique Programs (e.g., Worcester Polytechnic Institute, Olin, or James Madison University). Unique programs like Worcester Polytechnic Institute are the leaders in teaching students engineering within a global context (Vaz and Pederson, 2002), and it was hypothesized that students and faculty from these institutions will approach problems with more of an emphasis on global contexts compared to the other groups. These institutions explicitly advertise how they create globally competent engineers and explain how they do-so through their course development.

Additionally, these institutions are often mentioned in literature about how they have attempted to craft global engineers through their unique like Worcester Polytechnic Institute.

Recruitment

Participants were recruited by contacting chemical engineering department heads and academic assistants from every ABET accredited chemical engineering program in the United States. The recruitment email (Appendix B) was approved by the Bucknell University Institutional Review Board as this is human subjects research. Faculty or administrators were asked to forward the survey link or the recruitment email to their students and colleagues so that they may participate. The survey was also posted in the American Society of Engineering Education's Chemical Engineering Division newsletter and the call for participation can be found in Appendix C.

Thematic Analysis

The survey responses were analyzed using thematic analysis. Thematic analysis is a widely used method that offers understanding into common themes or patterns in a set of data (Braun and Clarke, 2012). This allows for observations to be drawn from the group rather than an individual. Braun and Clarke write, "This method, then, is a way of identifying what is common to the way a topic is talked or written about and of making sense of those commonalities," (2012). Thematic analysis is not limited to identifying a singular theme as many themes can be identified. However, not every pattern identified may be relevant to the chosen research question.

Thematic analysis is both flexible and accessible (Braun and Clarke, 2012), which makes it a useful and insightful method of data analysis for qualitative research. Several researchers have outlined different steps to perform thematic analysis, but overall, they are all similar. For this

thesis I performed thematic analysis as outlined by Jodi Aronson (1994). The first step is to collect the data and begin to identify common themes in the data set. The patterns are then delved into further and are catalogued. For example, the data that fits under a theme is catalogued and provides evidence for an identified pattern. Cataloguing is different for every researcher. I color-coded the sentences of portions of a response that served as evidence for demonstrating consideration for economic factors, for example. Aronson lists the next step as identifying sub-themes within the aforementioned described patterns. Themes are defined as, "Conversation topics, vocabulary, recurring activities, meanings, feelings, or folk sayings and proverbs" (Taylor & Bogdan, 1989). The themes are identified by "Bringing together components or fragments of ideas or experiences, which often are meaningless when viewed alone" (Leininger, 1985). The themes are then brought together to create a story that describes the whole group's thoughts (Aronson, 1994). The final step is to defend the findings. Aronson explains that the researcher must look at literature to build a strong foundation to present one's findings. By utilizing literature, the researcher is better able to infer about the collective group. Aronson writes, "When the literature is interwoven with the findings, the story that the interviewer constructs is one that stands with merit," (1992).

Statistical Analysis

Using the survey data, contingency tables were made, and the tables are then inserted into JMP Pro, a predictive analytical statistical software. Due to a small sample size, a Fisher's Exact Test was used to analyze the data (appropriate for subsamples < 5). JMP Pro then calculates a p-value, which can be used to determine if the data is trending or if there is a strong correlation. Strong correlations will result in a p-value below 0.05 and trending data correlates to a p-value between 0.10 and 0.05.

COVID-19's Impact on the Project

Due to the extenuating circumstances, the interviews that were lined up to be completed after Bucknell University's Spring Break had to be cancelled and could not be completed within the required time frame indicated by the Bucknell Honors' Council. On March 13, 2020 Dr. Ron Jacob wrote:

> "The timeline can not change in order to have commencement on schedule. While we recognize the variety of stress, and the ill effects of this stress on writing, we also want to keep the reward for successful completion of your Honors Thesis which results in recognition during commencement."

Similar to Bucknell University, the Universities and Colleges that were going to 'source' the participants sent students off-campus and began remote-learning. Because of this, professors and departments that were previously going to assist in gathering participants for the project, after buying into the project's goals and research question, had to scramble to reorganize their students' learning as well as ensure the safety of their faculty and students. In short, ensuring that there would be ample participants was no longer, and should not have been, the program's biggest concern. In summation, the actual interviews were not able to take place, but the framework was still crafted.

Interview Data Analysis Methodology

Through the consultation with Dr. Elizabeth Reddy and Dr. Elif Miskioglu, interviews were going to supplement the survey due to sample size insufficiency. Small sample sizes are often perceived to threaten the validity of the data collected (Vasileiou et al., 2018). However, interviews are able to delve deeper into an individual's thinking than a survey can. As richer information is collected, fewer participants are needed because more of the information collected

is usable (Morse, 2000). Additionally, open-ended questions, like the ones that were to be asked, have been empirically found to produce richer responses or data (Ogden and Cornwell, 2010). The sample size that was going to be collected was going to be based on informational redundancy. Informational redundancy, proposed by Lincoln and Guba, is the point at which no new data is being collected by continually interviewing people (1985). Essentially, there is no need to continually interview people if the same information is being recorded.

Determining when saturation has occurred would be supported by a cumulative frequency graph, which will support when saturation was determined by the researcher (Francis et al., 2010). Another way to determine saturation is through the Comparative Method for Theme Saturation (Constantinou et al., 2017). Through this methodology, the findings of new interviews are compared to older interviews to determine if new themes are emerging and if not then a "saturated terrain" has been established (Constantinou et al., 2017). In order to reduce bias, re-ordering interviews to re-analyze the data should be done to confirm saturation (Constantinou et al., 2017).

While the survey was broad in-scope (looked for trends based-on school, study abroad experiences, career aspirations, etc.), the interviews were going to be narrower in-order to be more generalizable. Additionally, by narrowing the scope, the number of interviews required before saturation occurs would most likely be reduced. Groups that were potentially going to be explored were National Grand Challenge Scholar Program members, Engineers Without Borders Members, Study Abroad Immersion Participants, etc.

Interview Guide

The intended interview was going to be semi-structured in format and the following guide was to be used by interviewers. Additionally, software that records the interviews and creates interview transcripts was to be used in order to reduce any feeling of judgement by the interviewee as no handwritten notes were going to be taken. The five questions that were asked in the survey are the questions referenced in the subsequent guide.

Remember: This interview is semi-structured, so while there are required questions that must be asked the eb-and-flow of the interview may change based on each participant. Additionally, it is important that you read Table 2.0 before every interview to re-familiarize yourself with the types of responses you can elicit, their purpose, and examples.

1. *Read the IRB Statement*. It is imperative that the participant feels comfortable and any questions they have about the study can be answered.
2. *Have the participant list out their responses to the first question.* Participants should have no problem listing their initial thoughts or thinking. While the participant is doing all of the talking, this does not mean you (the interviewer) is passive as responses that are considered vague require additional probing. If responses are vague ask the participant to clarify or provide further detail. The participant should be free to list as many ideas as they can in order to allow them to potentially hit all of the factors–the interviewer should not interrupt the interviewee in order to not break their train of thought.

3. *Have the participant narrow down their list*. In order to find out what factors are of most important to the participant, ask them to narrow down their responses to a few ideas that they deem most important.
4. *Have the participant expand on their most important thoughts.* The participant should be asked why they deemed the responses they chose as most important. Interviewers should probe for reasonings that are based on experiences or are concrete. For instance, did they have a job experience that they worked with frequently? Do they have a concentration in environmental engineering?
5. *Ask the participant what their least important responses were.* Ask the participant to expand on their thoughts and how they came to this conclusion. When asking participants for their least important thoughts it may be a good idea to assure the participant that there are no incorrect responses.
6. *Repeat steps 2-5 until all of the required questions are asked.*
7. *Collect the participants demographics.* If the participant is more comfortable with filling out their demographics without you (the interviewer) present, then allow them to do-so or send them a link to the responses. If a link is sent, be sure to include an identifier, so the correct demographics are linked to the correct interview transcript.
8. *Thank the participant for their time and answer any of their unanswered questions.*

Research Questions

This thesis was conducted to look into the differences in chemical engineering problem-solving between and among students and faculty. More specifically, this thesis looks into the frequency that chemical engineers incorporate global themes as outlined by ABET (global, cultural, social, environmental, and economic) into their problem-solving. This study compares the results of its

key demographics (senior-year students and faculty) and whether experiences of the individuals may have led to a higher likelihood of incorporating global themes into problem-solving. There were five research questions that were explored, and they are as follows:

1. Does having a study abroad experience change how individuals approach their problem-solving?
2. Does the type (PUI, Research Intensive, Unique) of institution students attend impact their approach to problem-solving?
3. Does the career aspiration of students impact how they approach problem-solving?
4. Does having industry experience impact how faculty approach problem-solving?
5. Does having international collaborators or traveling for work impact how faculty approach problem-solving?

Research Prompt

Participants were presented with a series of questions that relate to the following prompt:

> *You are a chemical engineer working for a company that designs and installs water purification systems. Currently, you are the lead engineer on the design of a water purification project in a rural community. Please answer the following questions in that context.*

The prompt is intentionally open-ended in order for the respondent to approach the subsequent prompts in a way that does not steer their problem-solving. Additionally, the prompt represents something of interest to engineers. In the Bucknell University Engineering Curriculum, Engineering 100 students are tasked with getting water to El Porvenir residents, who reside on a mountain top in Nicaragua, year-round–a fairly similar problem. A criticism for open-ended problems, in regard to gauging public opinion, is that people choose to not answer the prompt

because they are unable to articulate their thoughts and beliefs (Stanga and Sheffield, 1987). According to Geer (1988), this means that open-ended questions often measure education rather than substance of thought. However, this thesis looks at how different styles of education and different universities and backgrounds shape one's problem-solving, so measuring the results of one's education is of interest.

After reading the prompt, the respondents are then asked the following questions:

1. What important factors will you consider in your design and why?
2. Who would you include on your design team?
3. What other individuals or groups would you want to discuss your work with *before* the implementation?
4. What other individuals or groups would you want to discuss your work with *during* the implementation?
5. What other individuals or groups would you want to discuss your work with *after* the implementation?

After responding to the above questions, participants are then asked a series of demographic and experience questions in order to see if participants of similar backgrounds or experiences share approaches to problem-solving.

Limitations

Qualitative research often includes prefaces about the limitations or potential weaknesses of the study. While this survey was sent out to every chemical engineering accredited institution in the

country, the results of this study are not generalizable due to the small sample size of respondents.

Addressing Sample Size

Overall, there were 39 responses. However, the 39 responses were from two different populations (faculty and senior-year students), which is not enough responses to statistically represent either population with a high confidence rate.

In 2012, there were 8,344 chemical engineering graduates that received a Bachelor's degree in the United States (NSF, 2014). Using this number as an estimate for the amount of chemical engineering undergraduate seniors currently, the formula to calculate the required sample size can be seen below (Krejcie and Morgan, 1970):

$$n = \frac{X^2 * N * P * (1-P)}{(ME^2 * (N-1)) + (X^2 * P(P-1))} \qquad (1)$$

Where:

n is sample size

X_2 is the Chi_2 for the chosen confidence level at 1 level of freedom

N is the population size

P is the population proportion

ME is the chosen Margin of Error (as a proportion)

At a 95% confidence level and a 5% margin of error, a population of 8,344 would require 368 respondents to be statistically representative. While the survey responses collected cannot be statistically representative, the responses were used to guide the subsequent interviews.

Additionally, the survey responses can still provide potential trends or insights amongst groups as the 23 responses were of high-quality and were not simply "checking boxes" or a standard Likert scale.

The amount of chemical engineering faculty within the United States has to be estimated as that information is not readily available. The number of chemical engineering doctorates given out in a year was used as a rough estimate for the number of faculty within the United States. In 2015, 1,062 doctorates were awarded (ASEE). If 1,062 total faculty were assumed to teach in the United States, at a 95% confidence level and a 5% margin of error, a sample size of 283 would have to be collected.

Survey Results

The results of the survey are presented by showing the survey responders demographics, and explaining how the results were coded and prepared to be analyzed.

Collected Survey Demographics

While 148 survey responses were collected, only 39 responses were complete. The following figures show the collected demographics in groupings.

Figure 1 shows the breakdown of respondents by population (faculty or student), by gender, by ethnicity, and by the type of institution students attended.

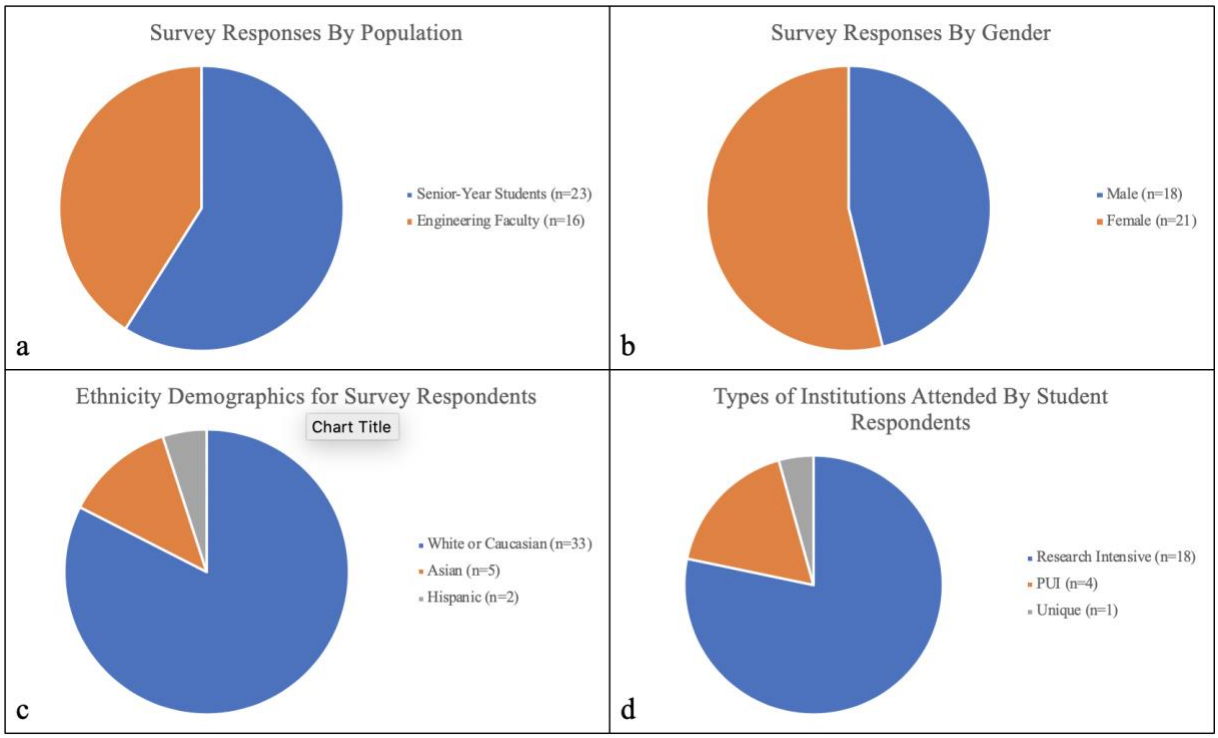

Figure 1: *In quadrant form, the collected survey demographics where (a) shows the breakdown of responses by faculty or students, (b) shows the breakdown of responses by gender, (c) shows the breakdown of responses by ethnicity, and (d) shows the breakdown of students by the type of institution they attend.*

If a respondent answered that they identified with more than one race than it was double counted. None of the respondents identified as Black/African American, which is a major population that is not accounted for within this study. Examples of some of the PUI's that responded were Bucknell University and Clarkson University. Some examples of research intensive programs that participated are University of Iowa, Ohio University, University of California Los Angeles, and Kansas State University. The student respondent that attends the unique institution attends Missouri University of Science and Technology. The survey responses were primarily from research intensive institutions and were largely from large state schools.

Figure 2 shows the breakdown of respondents by the extended international experience for students, the career aspirations of the student population, the type of institution faculty respondents work at, and the expatriate status of the faculty population.

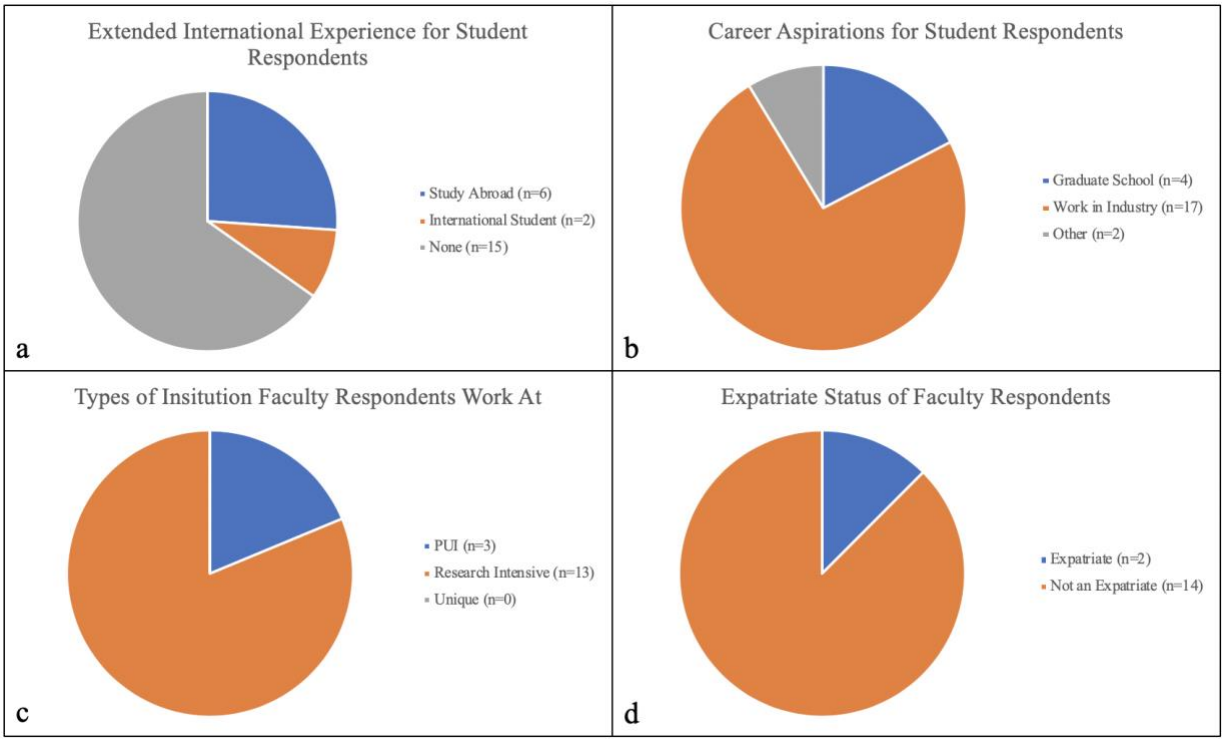

Figure 2: *In quadrant form, the collected survey demographics where (a) shows the breakdown of students by extended international experiences, (b) shows the breakdown of students by career aspiration, (c) shows the breakdown of faculty by the type of institution they work at, and (d) shows the breakdown of faculty by their expatriate status.*

Students were also asked if they were international students or had a study abroad experience as this was of interest as it was hypothesized that these two populations may be more attuned to global thinking based on their experiences. Additionally, student respondents were asked what their career aspirations were because it was predicted that students that anticipate working in industry may approach problems with an emphasis on business more so than those planning on

attending graduate school. Similar to the student respondents, faculty respondents were asked a variety of demographic-based questions to better understand their experiences to see if there would be any themes that were present for individuals with similar experiences. It was hypothesized that expatriates would be more attuned to global factors, so faculty respondents were asked whether they are an expatriate or not.

Figure 3 shows the breakdown of faculty respondents by whether they travel for work or have international collaborators, industry experience, or if they traveled for work or studied abroad during their schooling.

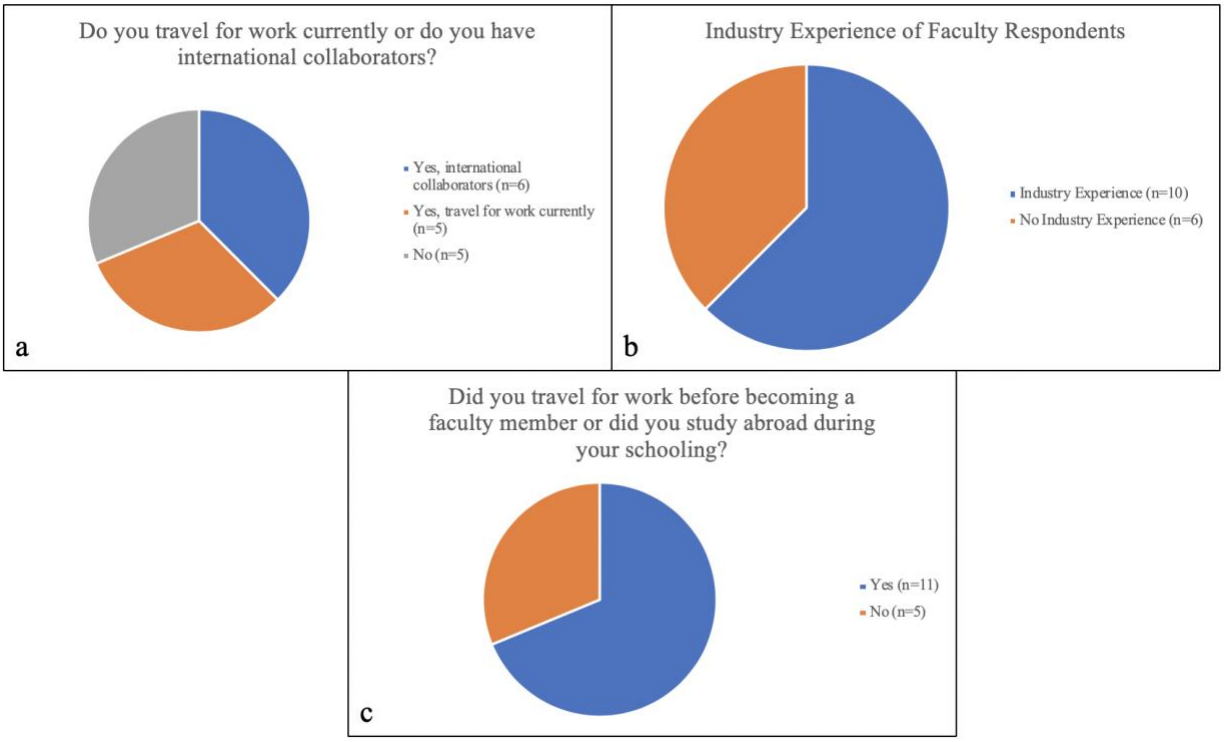

Figure 3: *In triangular form, the collected survey demographics where (a) shows the breakdown of whether faculty have international collaborators, travel for work, or have neither experience, (b) shows the breakdown of faculty industry experience, and (c) shows the breakdown of faculty by whether they traveled for work before becoming a faculty member or if they studied abroad during their academic career.*

Faculty were also asked if they currently travel internationally for work or if they have international collaborators. This question was of interest because it was hypothesized that faculty who either travel internationally or have international collaborators would answer the prompts with more of a global focus than faculty that do not travel internationally or have international collaborators. It was hypothesized that faculty with industry experience would answer the questions differently than faculty without industry experience, so faculty respondents were asked whether they had experience within industry. Similar to the student population, the faculty respondents were also asked whether they had a study abroad experience during their schooling. However, within this question they were also asked if they traveled for work before becoming a faculty member. The respondents were asked this because study abroad experiences were predicted to improve global outlook for individuals and similarly it would be predicted that traveling for work would yield similar results. Unfortunately, this question did not allow faculty respondents to separate their answers (i.e.: "Yes, study abroad", "Yes, travel for work", or "Both"), so when examining each sub-population's answers it will have to be assumed that traveling for work and studying abroad are fairly equivalent experiences.

Coding

The first pass for coding responses was to look at the respondents answer to the first question posed (What important factors will you consider in your design and why?). The responses were coded to correlate with the overarching themes for ABET requirement 4 (formerly 3h) which looks at global factors (cultural, social, environmental, and economic factors). It is important to note that Questions 3-5 were analyzed in a different manner, so those questions are not discussed under this coding section.

Question 1: What important factors will you consider in your design and why?

Global factors are being interpreted as represented by cultural, social, environmental, and economic factors. ABET prefers to use general terms to not stifle or impede an institution's program development. As a result, the factors are not defined, nor do they explain what achieving each factor entails. This leads to self-defining each-term as it relates to this study. Analyzing the results is largely based on researcher interpretation; following guidelines as well as having a consistent analysis regimen yields analyses with low variability in judgement of the final coded responses. In this work, I define each subfactor as summarized in Table 3, noting that each is difficult to define due to many of the factors often being defined circularly or are extremely broad and open-ended.

Table 3: *The factors, a definition of what satisfies covering the factor, and examples that would cover the factor.*

Factor	Definition	Examples
Cultural	Considering the laws or regulations of the community or area, taking note that rural communities may differ from other communities, or taking into consideration the habits or voice of the inhabitants.	Local laws or regulations, farming community, voice from the community, the required water usage
Social	Safety, the population within or around this community, the workforce, human impact of the project, the usability or feasibility of the filtration system for the population's water usage.	Safety, mitigating disrupting the community's lives, should the plant be designed to filter beyond the minimum requirement?
Environmental	Environmental impact of their design if the responses included a nod to geography, the location of the plant, environmental protection agencies (i.e., EPA), or sustainability.	Environmental factors, rural area, where the plant was going to be, EPA regulations
Economic	Any response that made a nod to economics or cost satisfied this factor.	Profit, budget, operating cost, capital cost

Figure 4 shows the number of coded responses that covered the factors of interest for the first-posed question “What important factors will you consider in your design and why?”

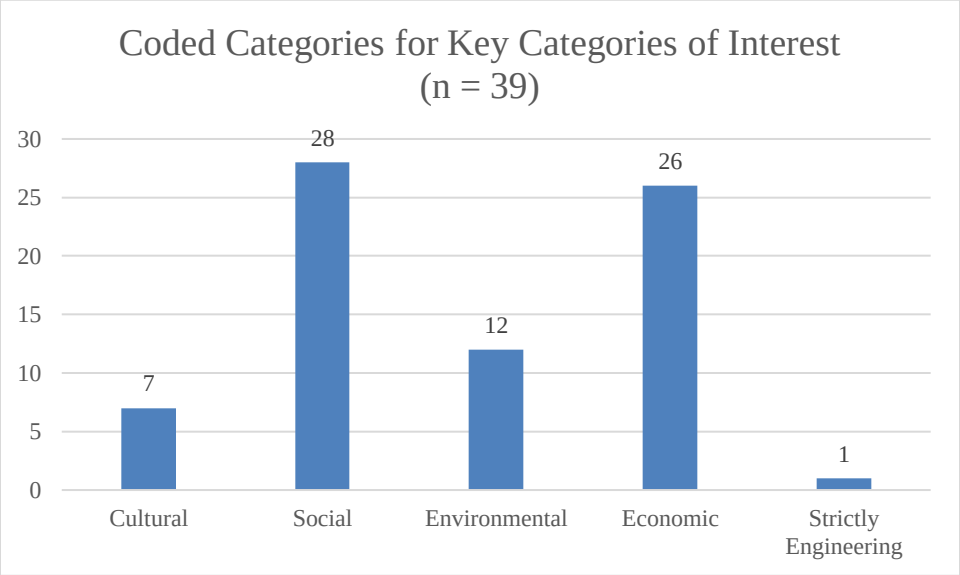

Figure 4: *The number of respondents that successfully covered the various factors ABET Outcome 2 looks for within the first question of this study where the overall population was 39.*

Populations were then compared to see if there were differences based on experiences as well as population (faculty or senior-year students). Figure 5 shows what categories faculty respondents considered when answering the first question, “What important factors will you consider in your design and why?”

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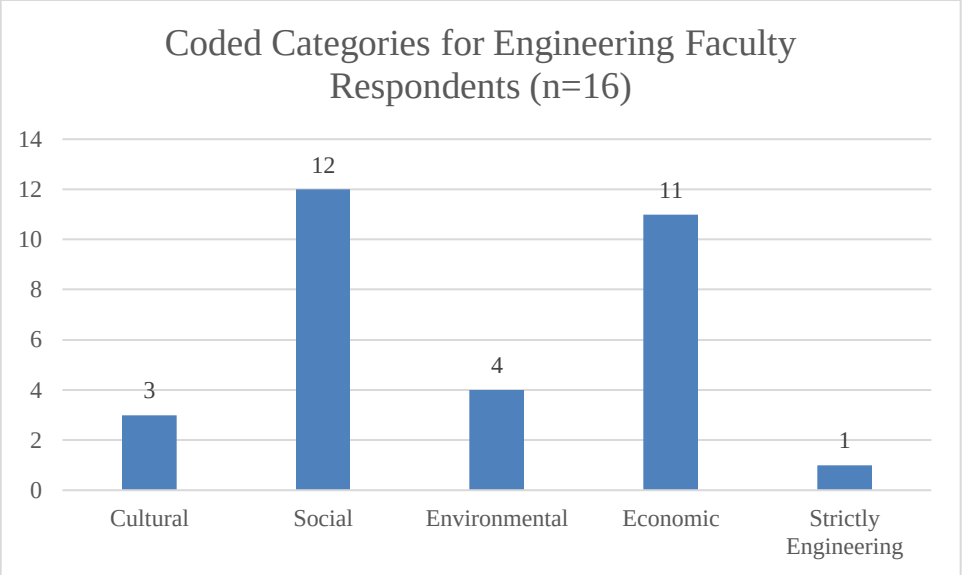

Figure 5: *The factors considered by the faculty respondents to the first-posed question within the survey where the total faculty population is 16.*

Figure 6 shows what categories senior-year student respondents considered when answering the first question "What important factors will you consider in your design and why?"

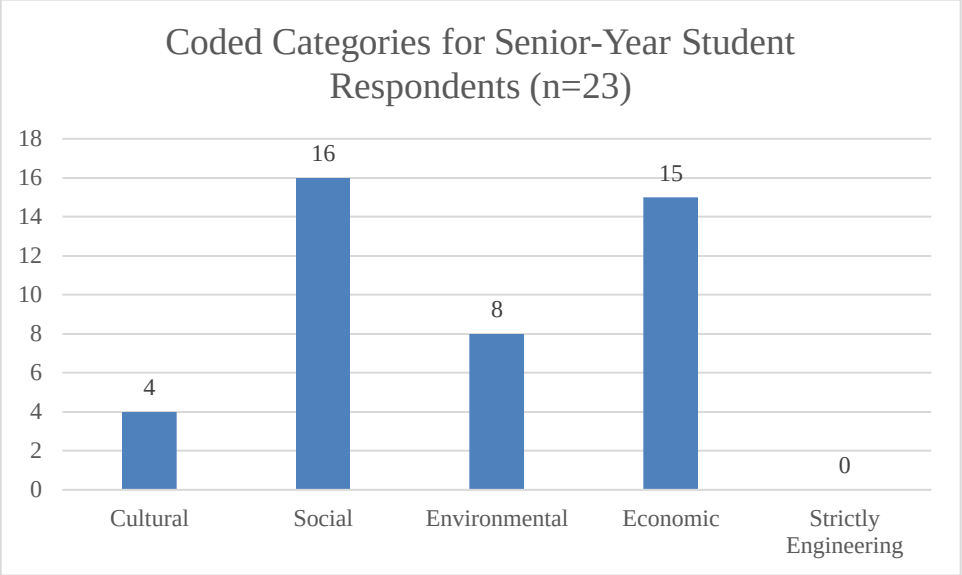

Figure 6: *The factors considered by the senior-year student respondents to the first-posed question within the survey, "What important factors will you consider in your design and why?" where the total student population is 23.*

Question 2: Who would you include on your design team?

This question looked at the first step in the Cooperative Problem Solving (CPS) framework. The first stage in CPS, according to Wooldridge and Jennings, is potential recognition (1999). In the potential recognition stage, individuals are tasked with identifying a list of candidates who would successfully be able to help solve the problem at hand (Wooldridge and Jennings, 1999). In this step, the person forming the team is interested in identifying the person of interest's abilities, opportunities, and willingness to join the team (Dignum et al., 2001). However, the question posed as well as the interest of this study is only interested in a respondent's ability to identify someone's abilities. According to Dignum et al., "The aspect of ability considers whether the agents can perform the right type of tasks. It does not depend on the situation, but may be viewed as an inherent property of the agent itself," (2001). Agents, in this context, refers to the

individuals being considered to join the prospective team. Within Dignum et al.'s framework of thinking, the problem posed does not depend on the task, but the ability of the individual, so the type of question posed should not impact who a respondent decides to put on their team.

Responses were again analyzed by looking for how respondents covered the global factors of interest. That is, respondents were scored based on if they listed individuals or groups that cover the cultural, social, environmental, and economic factors. Table 4 shows a list of the factors, a definition of what would be counted as successfully covering the factor, and an example of a response received that would be counted.

Table 4: *The factors, a definition of what satisfies covering the factor, and examples that would cover the factor.*

Factor	Definition	Examples
Cultural	Someone who works with the community to ensure that the project satisfies their needs or that the project does not infringe on their township or civilization.	Community leaders, public officials, local government, local engineers, local representatives from public works, etc.
Social	Someone who works at ensuring public safety and public health as a result of the project.	Safety engineers, microbiologists, quality engineers, biologists, etc.
Environmental	Someone that directly works in maintaining environmental ethics or ensures the environmental health as a result of the project.	Environmental engineers, environmental scientists, geologists, etc.
Economic	Someone who directly works with the financing of the project or works in servicing the financial needs of the project.	Accountants, economists, financiers, company board members, vendors, cost engineers, etc.

Figure 15 shows the number of times the factors were successfully covered by all survey respondents.

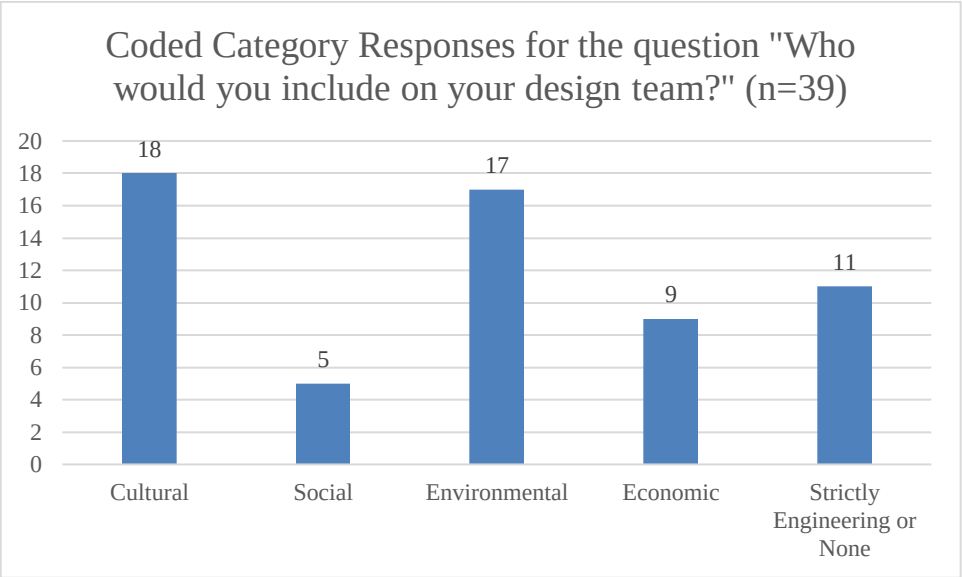

Figure 15: The number of respondents that covered each factor of interest in the second posed question, “Who would you include on your design team?” (n=39).

Analysis

The data will be presented in terms of the question asked and by the following hypotheses:

(i) Having a study abroad experience would increase the likelihood that participants included the global factors of interest.

(ii) The type (PUI, Research Intensive, Unique) of institution students attended would impact how they approached the problem.

(iii) The career aspirations of students would impact how they approached problem-solving.

(iv) Having industry experience would impact how well faculty took into consideration global factors.

(v) Having international collaborators or traveling for work would impact how well faculty approached the problem-solving.

Additionally, a summary table of all of the results for questions 1-5 can be found in Appendix D-F.

Question 1: What important factors will you consider in your design and why?

Study Abroad and International Experiences

Student Population

A contingency table was made for student respondents and separate students by the type of institution they attend. It was hypothesized that there would be differences between the groups as those with study abroad experiences or international students were predicted to out-perform those with neither experience. This table can be seen in Table 5.

Table 5: *The number of coded responses for student respondents that had a study abroad experience, are an international student, or are/have neither.*

Categories	Study Abroad Experience (n=6)	International Student (n=2)	Neither (n=15)
Cultural	1	0	3
Social	3	1	12
Environmental	3	0	5
Economic	5	0	10
Strictly Engineering	0	0	0

A Fisher's Exact test p-value of 0.8921 indicates that there is no statistical difference in responses between these groups, contrary to the hypothesis.

Previous cited literature and policy recommendations have pushed for students to partake in study abroad experiences as it is thought to increase global learning. However, only 2.1 percent of American students partake in a study abroad experience during their schooling (Donnelly-Smith, 2009). Braskamp et al.'s study found that learning abroad improves global learning and its development (2009). Additionally, their findings were consistent with the National Survey of Student Engagement, which found that studying abroad is moderately correlated with higher-order thinking (2007). However, their study found that studying abroad did not change students' social concern for others (Braskamp et al., 2009). In relation to this study, the cultural and social factors were scored, essentially, on whether students were able to show concern for safety or were able to identify that people's livelihoods may be impacted. In other words, students were demonstrating concern for others.

Faculty Population

Faculty that traveled for work before becoming a faculty member or studied abroad in college were hypothesized as more likely to consider global factors when thinking about problem-solving. Table 6 shows the results for the coded responses for those that either traveled for work before becoming a faculty member or had a study abroad experience and those that had neither.

Table 6: *The coded responses for those that traveled for work or had a study abroad experience and those that had neither.*

Categories	Traveled for Work Before Becoming a Faculty Member or had a Study Abroad Experience (n=11)	Neither (n=5)
Cultural	2	1
Social	8	4
Environmental	2	2
Economic	6	5
Strictly Engineering	1	0

A Fisher's Exact test p-value of 0.9355 indicates that there is no statistical difference in responses between these groups, contrary to the hypothesis.

Comparing the Faculty and Student Populations

One of the key questions that was asked to both the faculty and student respondents covered, for the students, if they partook in a study abroad experience, or if they were a faculty member either a study abroad experience or if they traveled for work before becoming a faculty member.

Table 7 shows the number of respondents that had this shared experience for both groups and brought in the global factors of interest into their problem-solving.

Table 7: *The number of respondents that covered the categories of interest and shared commonality between studying abroad or traveling for work before becoming a faculty member or studying abroad.*

Categories	Faculty (n=11)	Students (n=6)
Cultural	2	1
Social	8	3
Environmental	2	3
Economic	6	5
Strictly Engineering	1	0

A Fisher's Exact test p-value of 0.0044 indicates that there is a statistical difference in responses between these groups, contrary to the hypothesis.

This was unexpected as it was hypothesized that students that traveled abroad and faculty with similar experiences would statistically answer the questions in a similar manner. However, in this sample, faculty respondents that studied abroad or traveled for work before becoming a faculty member did not, compared to the student population, consider environmental factors, which led to the large statistical difference between the two groups. Furthermore, it is possible that the "gains" made from studying abroad or traveling for work can diminish over time and most student respondents who answered the survey recently completed their immersion.

Type of Institutions Attended

The next factor examined was whether the responses of students at different types of educational institutions varied. It was hypothesized that student responses would vary depending on the type

of institution they attend. Table 8 shows the differences between students attending Unique, PUI, or Research Intensive Programs.

Table 8: *The number of coded responses for student respondents attending various types of academic institutions.*

Categories	Unique (n=1)	PUI (n=4)	Research Intensive (n=18)
Cultural	0	0	4
Social	1	2	13
Environmental	0	1	7
Economic	1	2	12
Strictly Engineering	0	0	0

A Fisher's Exact test p-value of 0.4851 indicates that there is no statistical difference in responses between these groups, contrary to the hypothesis.

This was unexpected because it was hypothesized that there would be a discrepancy in how students answered based on their institution. However, the discrepancy was anticipated amongst the unique institution students and the other students because the unique institutions structure their curricula with an emphasis on global learning (Vaz and Pederson, 2002). The small overall sample size is a cause for concern as well as no conclusions can be made as the unique student population only contained one respondent. These unique institutions have remade their curricula and shaped their student's experiences to hopefully produce engineers with a stronger global mindset, which is why they were of such interest. Global teaching can be challenging as the

learning objectives cannot be done with the current curricula or existing theories (Marsella, 2007), which furthers the interest to look into the potential success of these unique programs.

Career Aspirations

Student Population

The next experience of interest was the career aspirations for the student populations. It was predicted that those aspiring to enter industry would be more cognizant of global factors into their problem-solving. For instance, it would not be a reach to assume that those interested in entering industry would be more cognizant of economic factors than those interested in attending graduate school. Table 9 shows the results for the student population broken-down by career aspiration.

Table 9: *The number of coded responses for student respondents that intend on entering industry, attend graduate school, or have other future aspirations.*

Categories	Working in Industry (n=17)	Graduate School (n=4)	Other (n=2)
Cultural	2	1	1
Social	12	2	2
Environmental	4	2	2
Economic	10	4	1
Strictly Engineering	0	0	0

A Fisher's Exact test p-value of 0.6760 indicates that there is no statistical difference in responses between these groups, contrary to the hypothesis.

Comparing the Faculty and Student Populations

It was also of interest to compare the entire faculty population to the student population that plans on attending graduate school to see if there were similarities in the thinking of those that have already attended graduate school and those that plan on attending graduate school. It was hypothesized that the student population that aspired to attend graduate school would be similar to the faculty population. Table 10 shows the number of respondents that anticipate attending graduate school or have already attended graduate school, that brought in global factors into their problem solving.

Table 10: *The number of respondents that covered the categories of interest and shared commonality between attending graduate school or planning on attending graduate school.*

Categories	Faculty (n=16)	Student (n=4)
Cultural	3	1
Social	12	2
Environmental	4	2
Economic	11	4
Strictly Engineering	1	0

A Fisher's Exact test p-value of 0.8812 indicates that there is no statistical difference in responses between these groups, in agreement with the hypothesis.

Students with plans to attend graduate school were hypothesized to answer questions similarly to faculty because it was predicted that there might be similar thinking amongst groups that pursue higher education. In retrospect, those that pursue graduate school are not homogenous. However,

the statistical analysis did show that the students interested in pursuing graduate school and the faculty members were not statistically likely to cover the global factors of interest differently.

Industry Experience

The next factor examined is whether the faculty with industry experience differed from the faculty without industry experience. It was hypothesized that the groups would answer the question differently depending on whether or not the faculty members have industry experience. Table 10 shows the differences between the two aforementioned populations.

Table 11: *The number of coded responses for faculty respondents with and without industry experience.*

Categories	Industry Experience (n=10)	Without Industry Experience (n=6)
Cultural	2	1
Social	7	4
Environmental	3	1
Economic	7	3
Strictly Engineering	0	1

A Fisher's Exact test p-value of 0.8336 indicates that there is no statistical difference in responses between these groups, contrary to the hypothesis.

While no literature was found to either support or refute the notion that faculty with industry experience and faculty without industry experience exhibit different levels of global competency, there has been research supporting that faculty with industry experience have a stronger

commitment to teaching (Fairweather and Paulson, 1996). Fairweather and Paulson's research found that for engineering and natural science faculty members, faculty with industry experience spend more time teaching than that is required by their contracts (1996). Additionally, faculty members with industry experience were also found to be more committed to their jobs as they were less likely to think about changing jobs (Fairweather and Paulson, 1996). While this work did not find differences in the global competency of faculty with and without industry experience, future longitudinal work could be done to examine how these competencies grow as students take classes with faculty members with and without industry experience.

International Collaboration

The next experience of interest was if the faculty travel for work or have international collaborators. It was hypothesized that those that either travel for work or have international collaborators would have answers that are better aligned with ABET outcome 2 (formerly 3h). Table 12 shows the results of the coded responses to the first question posed.

Table 12: *The amount of coded responses for faculty respondents with international collaborators, those that travel for work, and those that have/do neither.*

Categories	Travel for Work (n=6)	International Collaborators (n=5)	Neither (n=5)
Cultural	1	1	1
Social	6	2	4
Environmental	0	2	2
Economic	5	3	3
Strictly Engineering	0	1	0

A Fisher's Exact test p-value of 0.6665 indicates that there is no statistical difference in responses between these groups, contrary to the hypothesis.

Faculty that travel for work and have international collaborators were predicted to perform better than faculty that did neither. Within these two groups, faculty that have international collaborators were hypothesized to outperform both other groups (those that travel for work and those that do not travel for work nor do they have international collaborators), which did not come to fruition. This hypothesis was based on research done in nursing. In nursing, international collaborations are able to develop "culturally aware global leadership skills" in an exceptional manner (Garner et al., 2009). Additionally, international collaboration is able to link ethical accountability, leadership decisions, and advocacy issues in nursing (Leppa and Terry, 2004). Because of international collaboration's role in improving the education and development of nurses, it was predicted that similar findings would occur for chemical engineering faculty that collaborate with internationals.

It was hypothesized that traveling for work and having international collaborators would yield the same results. In other words; that is to say that having an international collaborator was predicted to improve one's consideration of global factors in problem-solving similarly to traveling for work. The consolidated results for these categories can be seen in Table 13.

Table 13: *The consolidated coded responses for those that travel for work or have international collaborators and those that have neither.*

Categories	Travel for Work or Have International Collaborators (n=11)	Neither (n=5)
Cultural	2	1
Social	8	4
Environmental	2	2
Economic	8	3
Strictly Engineering	1	0

A Fisher's Exact test p-value of 0.9204 indicates that there is no statistical difference in responses between these groups, contrary to the hypothesis.

Even after consolidating the two groups based on the assumption that traveling for work or having international collaborators would yield a similar result, there was no statistical difference between these respondents and those that do not have these experiences.

Examining High Performing Students

If a student received notation for three or more of the four coded categories, then they were marked as high performing within the context of this study. Using this metric, there were six high-performing students. Table 14 shows what categories the group successfully covered within their problem-solving.

Table 14: *The coded categories covered by the six high-performing individuals.*

Categories	Number of High-Performing Students that Brought the Factor into their Problem-Solving (n=6)
Cultural	3
Social	6
Environmental	5
Economic	5

Within the context of high-performing students, the cultural factor was the least frequently covered. This is consistent with the responses of the entire student population and not unique to high-performers, which may indicate that the cultural factor is the hardest to cover or the hardest to demonstrably cover. This factor was also one of the most difficult to define and requires a deep understanding of a problem. For example, in 2018, the Fort Belknap Indian Community and the Rosebud Sioux Tribe of South Dakota sued the United States of America under President Trump (NPR, 2018). The two tribes contended that the Keystone XL pipeline, the impetus of the lawsuit, did not study neither how the project would affect their water system nor how it would disrupt their sacred lands (NPR, 2018). Technically, the proposed pipeline would solve the problem that it was meant to; the project was intended to reduce the dependence on foreign oil and transform the United States to be more energy independent as well as to reduce energy costs. President Trump, when announcing the presidential permit for the project to commence, said:

> "It's a great day for American jobs and a historic moment for North American and energy independence. This announcement is part of a new era of American energy policy that will lower costs for American families — and very significantly — reduce our dependence on foreign oil, and create thousands of jobs right here in America," (WhiteHouse.gov, 2017).

While the project is successful in the typical sense of problem-solving it failed to acknowledge the cultural significance of the land and people that it would impact. Whether the original engineers or businesspeople thought about this when considering solutions to improve the energy infrastructure of the United States cannot be known, but regardless a solution that circumvented these sacred lands would require a deeper understanding of the cultural significance of the land than that was used.

All of the students that were classified as high performing attended a research intensive institution. While this was unexpected, the sample size that completed the entire survey is too small to make any significant judgements of an institution's effect on how they incorporate global factors into their problem-solving. The breakdown of experiences of the six high-performing individuals can be seen in Table 15 below.

Table 15: *The breakdown of experiences of the six high-performing senior-year students.*

Experiences	Number of Students that Shared this Experience
Study Abroad or International Student	1
Aspires to Work in Industry	2
Aspires to attend Graduate School	2
Other Aspirations	2

The sample size of the high-performing students is too small to make any conclusions. However, as previously mentioned, it was surprising to not have more high-performing study abroad

students as that was a hypothesis that was strongly anticipated based on research and colloquially thought principles.

Examining High Performing Faculty

Similar to the student population, if a faculty member received notation for three or more of the four coded categories then they were marked as high performing within the context of this study. Using this metric, there were two high-performing individuals. Table 16 shows what categories the group successfully covered within their problem-solving.

Table 16: *The coded categories covered by the six high-performing individuals.*

Categories	Number of High-Performing Students that Brought the Factor into their Problem-Solving
Cultural	3
Social	6
Environmental	5
Economic	5

Question 2: Who would you include on your design team?

The overall comparison of the faculty and student populations can be found in Table 17.

Table 17: *The number of coded responses that covered the factors of interest in question 2 of the survey.*

Categories	Faculty (n=16)	Student (n=23)
Cultural	8	10
Social	2	3
Environmental	4	14
Economic	5	4
Strictly Engineering or None	4	7

A Fisher's Exact test p-value of 0.4795 indicates that there is no statistical difference in responses between these groups.

While the groups are statistically the same, on a percentage basis students (60.9%) covered the environmental factor more readily than faculty (25%). It would be expected that the student population would successfully cover the Environmental factor more readily than their faculty counterparts because studies have found that younger Americans are more environmentally conscious than older generations (Pacific Standard, 2018). Johnson and Schwadel hypothesize that this is because younger generations are more likely to have environmental awareness and education within their schooling (2018). Additionally, they hypothesize that individuals may tend to care less and less about the environment as they age because they are less likely to be

exposed to the ideology (2018). However, this study did not ask respondents for their age so a breakdown of results by age group cannot be done.

Study Abroad and International Experiences

Student Population

Additionally, whether the students had a study abroad experience or were an international student was of interest. This was hypothesized to improve students' consideration for global factors as literature would suggest that those students would be more apt to take the global factors into consideration when solving a problem. Table 18 shows how many senior-year students with a study abroad experience or are international students and those without a study abroad experience or are not an international student successfully covered the factors of interest.

Table 18: *The number of coded responses that covered the factors of interest broken-up by whether students had a study abroad experience or are an international student.*

Categories	Study Abroad Experience or International Student (n=8)	Neither (n=15)
Cultural	6	4
Social	1	2
Environmental	5	8
Economic	2	2
Strictly Engineering or None	1	6

A Fisher's Exact test p-value of 0.4439 indicates that there is no statistical difference in responses between these groups, contrary to the hypothesis.

While it was hypothesized that students with study abroad experiences or students that were international students would answer questions differently than those that did not share those experiences, similar to the first question, this finding was not statistically found. It is possible that this study does not capture the growth that occurs over one's study abroad tenure. Future iterations may look to examine group's global mindedness through existing tests like the Global-Mindedness Scale (Hett, 1993) or the Intercultural Sensitivity Index (Olson and Kroger, 2001), which when administered have found that students that study abroad have higher intercultural proficiency than students that do not travel abroad during their undergraduate schooling (Kehl and Morris, 2007; Clarke et al., 2009). It is also possible that the small sample size was not able to capture these findings or trends. Additionally, interviews may be a better methodology to capture these findings as the administered survey may not have been best equipped to capture these findings.

Faculty Population

Faculty were also asked whether they traveled for work prior to becoming a faculty member or if they partook in a study abroad experience during their schooling. Like previously, it was predicted that respondents that traveled for work or partook in a study abroad experience during their schooling would cover the global factors with greater success than their counterparts. Table 19 shows the breakdown of factors covered by faculty that traveled for work prior to becoming a faculty member and those that partook in study abroad experience against those that have neither of those experiences.

Table 19: *The number of coded responses that covered the factors of interest broken-up by whether they travel for work prior to becoming a faculty member, if they partook in a study abroad experience during their schooling or did not have either experience.*

Categories	Traveled for Work or Partook in a Study Abroad Experience (n=11)	Neither (n=5)
Cultural	5	3
Social	2	0
Environmental	4	0
Economic	4	1
Strictly Engineering or None	2	2

A Fisher's Exact test p-value of 0.5480 indicates that there is no statistical difference in responses between these groups, contrary to the hypothesis.

The faculty respondents that partook in a study abroad experience or travel for work, similarly to the student population, were hypothesized to perform better, but this finding was not statistically substantiated in the context of this study.

Comparing the Faculty and Student Populations

Table 20 shows the breakdown of factors answered by faculty who either traveled for work before becoming faculty or partook in a study abroad experience and students who either have a study abroad experience or are an international student answered the second question. It was predicted that these groups would answer questions similarly based on their similar experiences.

Table 20: *The number of coded responses that covered the factors of interest broken-up by whether the faculty respondents traveled for work prior to becoming a faculty member or if they partook in a study abroad experience during their schooling and student respondents who either have a study abroad experience or are an international student.*

Categories	Faculty that Traveled for Work or Partook in a Study Abroad Experience (n=11)	Students with a Study Abroad Experience or are an International Student (n=8)
Cultural	5	6
Social	2	1
Environmental	4	5
Economic	4	2
Strictly Engineering or None	2	1

A Fisher's Exact test p-value of 0.9259 indicates that there is no statistical difference in responses between these groups, in agreement with the hypothesis.

Statistically, the faculty and students that have similar experiences based-on studying abroad are not likely to cover the global competencies differently than one another. However, the small sample size does not allow for any generalizations to be made.

Type of Institutions Attended

Student Population

Like before, it was of interest as to whether the type of institution students attended statistically correlated with what factors students successfully covered. Table 21 shows how many senior-year engineering students successfully covered the factors of interest broken-down by the type of institution they attend.

Table 21: *The number of coded responses that covered the factors of interest broken-up by the types of institutions attended.*

Categories	PUI (n=4)	Research Intensive (n=18)	Unique (n=1)
Cultural	3	7	0
Social	0	2	1
Environmental	1	12	0
Economic	0	3	1
Strictly Engineering or None	1	6	0

A Fisher's Exact test p-value of 0.1834 indicates that there is no statistical difference in responses between these groups, contrary to the hypothesis that the groups would differ.

Similar to the first question's analysis, it was predicted that individuals that attend unique institutions would more readily cover the global factors of interest as their programs are designed to imbue global competency within its students. However, the small sample size does not allow any relevant conclusions to be drawn based-on student institutions.

Career Aspirations

Student Population

Like in the first question posed, it was predicted that the career aspirations of students would impact who the students decided to include in their design team. For instance, it would not be a stretch that a student preparing to enter industry may be more likely to cover the economics

factor then a student preparing to enter graduate school. The breakdown of factors covered by students' career aspirations can be found in Table 22.

Table 22: *The number of coded responses that covered the factors of interest broken-up by students' career aspirations.*

Categories	Graduate School (n=4)	Industry (n=17)	Other (n=2)
Cultural	1	7	2
Social	1	2	0
Environmental	3	8	2
Economic	1	3	0
Strictly Engineering or None	1	6	0

A Fisher's Exact test p-value of 0.9846 indicates that there is no statistical difference in responses between these groups, contrary to the hypothesis.

Similar to the first question, students were not found to cover the global factors of interest differently based on their career aspirations. While this was not expected, no literature was found to refute this finding. However, future iterations, like in Professor Miskioglu's work (Miskioglu and Martin, 2016), may look at whether students completing internships impact how they perform on the administered survey.

Comparing the Faculty and Student Populations

The entire faculty population was also examined and compared to the students that were interested in pursuing graduate school. Like before, it was predicted that these groups would

answer the posed question similarly. Table 23 shows the factors covered by the faculty population and the students interested in attending graduate school.

Table 23: *The number of coded responses that covered the factors of interest broken-up by faculty respondents and students interested in pursuing graduate school.*

Categories	Faculty (n=16)	Students Interested in Pursuing Graduate School (n=4)
Cultural	8	1
Social	2	1
Environmental	4	3
Economic	5	1
Strictly Engineering or None	4	1

A Fisher's Exact test p-value of 0.5485 indicates that there is no statistical difference in responses between these groups, in agreement with the hypothesis.

As in the first question, faculty and students interested in pursuing graduate school are not statistically likely to cover the global competencies differently. However, the small sample size does not allow for generalization.

Industry Experience

Faculty Population

It was hypothesized that faculty with industry experience would cover the tested factors more readily. Table 24 shows the breakdown of factors covered by faculty with and without industry experience.

Table 24: *The number of coded responses that covered the factors of interest broken-up by students' career aspirations.*

Categories	Industry Experience (n=10)	No Industry Experience (n=6)
Cultural	4	4
Social	1	1
Environmental	4	0
Economic	4	1
Strictly Engineering or None	3	1

A Fisher's Exact test p-value of 0.4906 indicates that there is no statistical difference in responses between these groups, contrary to the hypothesis.

In the first analyzed question, faculty with and without industry experience were not statistically unequally likely to cover the global factors of interest. This finding was found again, but the small sample size limits the generalization of this finding.

International Collaboration

Faculty Population

Participants were also asked if they were expatriates, however, because there were only two expatriates in the sample size, this was not looked into further. The next set of experiences that was examined was whether faculty travel for work or have international collaborators. Participants who travel for work or have international collaborators were hypothesized to perform better as they were predicted to be more globally conscious. Table 25 shows the breakdown of factors covered by faculty who travel for work, have international collaborators, or do/have neither.

Table 25: *The number of coded responses that covered the factors of interest broken-up by whether they travel for work, have international collaborators, or do/have neither.*

Categories	Travel for Work (n=6)	International Collaborators (n=5)	Neither (n=5)
Cultural	3	2	3
Social	0	2	0
Environmental	1	1	2
Economic	0	2	3
Strictly Engineering or None	2	0	2

A Fisher's Exact test p-value of 0.4989 indicates that there is no statistical difference in responses between these groups, contrary to the hypothesis.

In the first posed question faculty members that travel for work, have international collaborators, and have neither of those were not statistically significantly likely to cover the factors of interest differently. This finding was repeated in the second question of the administered survey.

Additionally, like in the first-posed question's analysis, it was hypothesized that traveling for work and having international collaborators would be fairly similar experiences, so those categories were combined and were then compared to faculty with neither experience. Then, the condensed category was hypothesized to differ from the category where neither experience was shared. The contingency table for faculty that either travel for work or have international collaborators and those that have neither can be seen in Table 26.

Table 26: *The number of coded responses that covered the factors of interest broken-up by whether the faculty respondents travel for work or have international collaborators or do/have neither experience.*

Categories	Travel for Work or Have International Collaborators (n=11)	Neither (n=5)
Cultural	5	3
Social	2	0
Environmental	2	2
Economic	2	3
Strictly Engineering or None	2	2

A Fisher's Exact test p-value of 0.7953 indicates that there is no statistical difference in responses between these groups, contrary to the hypothesis.

While this result was not anticipated or hypothesized, it is the same result that was observed after analyzing question one's, "What important factors will you consider in your design and why?", results.

Questions 3-5: What individuals or groups would you want to discuss your work with before, during, and after the implementation.

The next three questions posed to respondents asked what individuals or groups would you want to discuss your work with before, during, and after the implementation. The purpose of this question was to see the types of perspectives the respondents would seek throughout their problem-solving. It was of particular interest to see if the surveyed population would seek out the input of the users, or the people affected, by the implementation of the design and at what point they would begin seeking their input.

In Management Information Systems (MIS), empirical studies have found that system designers design for the "heads of systems" (Tichy, 1974). Additionally, Tichy's study found that middle management was the primary reference group when seeking to alleviate problems and because of this received the most benefits from the newly designed systems or processes (1974). Because of this, secondary users were essentially ignored, and their jobs worsened (Bostrom and Heinen, 1977). Bostrom and Heinen concluded that systems are designed for a select-few user, typically in management, that reap the benefits of the newly designed systems (1977). This is problematic because the secondary users, not the managers, are the ones with constant exposure and interaction with the system (Bostrom and Heinen, 1977). Not only are these users constantly the one's being exposed to the new system, but the overall success of the new system is often

directly tied to how the secondary users utilize and interact with the system (Bostrom and Heinen, 1977).

The idea to include users in the designing of systems is not novel at all. Including users in system development has been described as a means to ensure that the system designed and implemented is successful (Boland, 1978). Research has found that system development is both a political process and a rational process (Franz and Robey, 1984). That is it the system is meant to deliver the desired goals, but is intertwined with the clients' or designers' biases or interests.

While participants are not being asked about how they would approach designing an information system, participants were asked about designing a system that can affect both primary and secondary groups. This question aimed to seek out if participants would seek groups typically thought-of as "secondary groups" throughout the implementation process. Types of occupations that are to be defined as secondary groups include the following: technicians, operators, locals, etc. Additionally, government officials, in the context of this study, would be seen as primary users as they are technically upper management as the township/city/etc. would be the company building the system.

Table 27 shows the number of respondents that chose to consult secondary groups in the development of the water treatment facility and at what stage they chose to-do-so.

Table 27: *The number of respondents that chose to consult secondary groups and at what stage of the implementation they were chosen to be consulted upon.*

	Before Implementation (n=38)	**During Implementation (n=38)**	**After Implementation (n=38)**
Secondary	29	24	30
Primary Only or None	9	14	8

Like before, the contingency table shown above was used to run a Fisher's Exact Test. The Fisher's Exact Test, with a significance level of 0.05, calculated a p-value of 0.2760. This provides evidence that there is no statistical difference in whether secondary groups were considered throughout the entire implementation process.

It was also of interest to see how often each respondent wrote a person or group that would qualify as a secondary group. Table 28 shows how often respondents included secondary groups as people of interest to consult throughout the implementation of the water treatment facility.

Table 28: *How often participants included that they would consult a secondary group throughout the implementation process.*

Times Secondary Groups Were Consulted	**Participants (n=38)**
Never	4
One Time	7
Two Times	5
Three Times	22

It was surprising to find that 57.9% of the time participants chose to consult secondary groups throughout the entire implementation of their design as prior research suggested that systems are not typically designed with much consideration to secondary groups. However, the participants are free of any company bureaucracy that may result in the systems being typically designed for primary users.

Before the faculty and student population responses were broken-down into their respective subpopulations, the student and faculty populations were compared to see if the likelihood of considering secondary groups was different. The contingency table for the student and faculty population can be seen in Table 29.

Table 29: *The number of students and faculty that chose to consult secondary groups and at what stage of the implementation they were chosen to be consulted upon.*

	Student Population (n=22)			**Faculty Population (n=16)**		
Stage	Before	During	After	Before	During	After
Secondary	15	11	17	14	13	13
Primary Only or None	7	11	5	2	3	3

A Fisher's Exact test p-value of 0.1372 indicates that there is no statistical difference in responses between these groups.

Secondary Group Consideration by Subpopulations

Just like in the first two questions asked, responses were analyzed by the subpopulations following the five hypotheses:

(i) Having a study abroad experience would increase the likelihood that participants include secondary groups throughout the implementation process.

(ii) The type (PUI, Research Intensive, Unique) of institution students attended would impact how they approached the problem.

(iii) The career aspirations of students would impact how they approached problem-solving.

(iv) Having industry experience would impact how faculty took into consideration secondary groups throughout the implementation process.

(v) Having international collaborators or traveling for work would impact how well faculty approached the problem-solving.

A summary table of the results can be found in Appendix F.

Study Abroad and International Experiences

Like previously, it was predicted that having international experiences may lead to respondents answering the prompts differently than if they did not have international experiences. Table 30 shows the number of students with study abroad experiences, who are international students, or have neither experience that considered secondary groups throughout the implementation of their design.

Table 30: *The number of students with study abroad experiences, are international students, or students with neither experience that chose to consult secondary groups and at what stage of the implementation they were chosen to be consulted upon.*

	Study Abroad (n=5)			**International Student (n=2)**			**Neither (n=15)**		
Stage	Before	During	After	Before	During	After	Before	During	After
Secondary	4	2	4	1	1	1	10	8	12
Primary Only or None	1	3	1	1	1	1	5	7	3

A Fisher's Exact test p-value of 0.6705 indicates that there is no statistical difference in responses between these groups, contrary to the hypothesis.

Coinciding with previous results, while it was hypothesized, based on literature, that study abroad or international students would vary from students with neither experience, the populations were not statistically different. The potential "gains" from having extensive international experiences was assumed to be similar for both the study abroad and international students, so they were combined into a single category to be compared to the students that have neither experience. The contingency table for this consolidation can be found in Table 31.

Table 31: *The number of students with study abroad experiences or are international students and students with neither experience that chose to consult secondary groups and at what stage of the implementation they were chosen to be consulted upon.*

	Study Abroad or International Student (n=7)			**Neither (n=15)**		
Stage	Before	During	After	Before	During	After
Secondary	5	3	5	10	8	12
Primary Only or None	2	4	2	5	7	3

A Fisher's Exact test p-value of 0.5666 indicates that there is no statistical difference in responses between these groups, contrary to the hypothesis that the groups would differ.

Faculty that traveled for work before becoming a faculty member or that studied abroad during their academic careers were compared to faculty that had neither experience as it was hypothesized that they would vary. The broken-down responses can be seen in Table 32.

Table 32: *The number of faculty with study abroad experiences or that traveled for work before becoming a faculty member and faculty with neither experience that chose to consult secondary groups and at what stage of the implementation they were chosen to be consulted upon.*

	Neither (n=5)			**Traveled for Work Before Becoming a Faculty Member or Studied Abroad (n=11)**		
Stage	Before	During	After	Before	During	After
Secondary	4	4	4	10	9	9
Primary Only or None	1	1	1	1	2	2

A Fisher's Exact test p-value of 1.000 indicates that there is no statistical difference in responses between these groups, contrary to the hypothesis.

This was not the expected result, but it is similar to the results from the previously analyzed questions. The faculty and students with similar international experiences were compared, under the hypothesis that they would be statistically similar, and the contingency table for the two populations can be seen in Table 33.

Table 33: *The number of students with study abroad experiences or are international students and faculty who traveled for work before becoming a faculty member or studied abroad during their academic career that chose to consult secondary groups and at what stage of the implementation they were chosen to be consulted upon.*

	Traveled for Work Before Becoming a Faculty Member or Studied Abroad (n=11)			**Study Abroad or is an International Student (n=7)**		
Stage	Before	During	After	Before	During	After
Secondary	10	9	9	5	3	5
Primary Only or None	1	2	2	2	4	2

A Fisher's Exact test p-value of 0.7699 indicates that there is no statistical difference in responses between these groups, in agreement with the hypothesis.

Type of Institutions Attended

It was also of interest to explore if students varied the level that they covered secondary groups based on their institution as it was hypothesized that they would. The contingency table for this can be seen in Table 34. Additionally, Appendix G

Table 34: *The number of students, broken down by their academic institution, that chose to consult secondary groups and at what stage of the implementation they were chosen to be consulted upon.*

	PUI (n=3)			**Research Intensive (n=18)**			**Unique (n=1)**		
Stage	Before	During	After	Before	During	After	Before	During	After
Secondary	2	1	3	12	9	13	1	1	1
Primary Only or None	1	2	0	6	9	5	0	0	0

A Fisher's Exact test p-value of 0.6577 indicates that there is no statistical difference in responses between these groups, contrary to the hypothesis.

The student population that was expected to vary the most from the other two was students attending unique institutions. While there was no statistical difference in the likelihood that the groups would consider secondary groups, the sample size of students attending unique institutions is far too small to make any generalizations.

Career Aspirations

The career aspirations, like in previous analyses, were examined to see if respondents were differently likely to consider secondary groups based on the career they were planning on pursuing. Like in the previous questions, it was hypothesized that the groups would vary. The career aspirations for students and their consideration for secondary groups can be seen in Table 35.

Table 35: *The number of students, broken down by their desired career, that chose to consult secondary groups and at what stage of the implementation they were chosen to be consulted upon.*

	Work in Industry (n=16)			**Graduate School (n=4)**			**Other (n=2)**		
Stage	Before	During	After	Before	During	After	Before	During	After
Secondary	11	9	13	2	1	2	2	1	2
Primary Only or None	5	7	3	2	3	2	0	1	0

A Fisher's Exact test p-value of 0.3885 indicates that there is no statistical difference in responses between these groups, contrary to the hypothesis.

Students that aspired to attend graduate school were then compared to the faculty respondents as it was predicted that those with similar career aspirations may answer questions similarly. These contingency table for these populations can be seen in Table 36.

Table 36: *The number of students who plan attending graduate school and the entire faculty population that chose to consult secondary groups and at what stage of the implementation they were chosen to be consulted upon.*

	Faculty (n=16)			**Students Aspiring to Attend Graduate School (n=4)**		
Stage	Before	During	After	Before	During	After
Secondary	14	13	13	2	1	2
Primary Only or None	2	3	3	2	3	2

A Fisher's Exact test p-value of 0.0652 indicates that there is no statistical difference in responses between these groups, in agreement with the hypothesis.

A p-value between 0.05 and 0.10 indicates a trending result, which means, in qualitative research, that while not a strong relationship there is a trend indicating a weak correlation. This was not expected, as it was hypothesized that the two groups would be very similar in how they approached problem-solving. Although the small sample size for each group cannot generalize the two populations as a whole.

Industry Experience

Whether or not faculty had industry experience was hypothesized to impact their problem-solving thinking. The contingency table for faculty with and without industry experience and their consideration for secondary groups can be seen in Table 37.

Table 37: *The number of faculty with and without industry experience that chose to consult secondary groups and at what stage of the implementation they were chosen to be consulted upon.*

	Industry Experience (n=10)			**No Industry Experience (n=6)**		
Stage	Before	During	After	Before	During	After
Secondary	9	8	8	5	5	5
Primary Only or None	1	2	2	1	1	1

A Fisher's Exact test p-value of 1.000 indicates that there is no statistical difference in responses between these groups, contrary to the hypothesis.

International Collaboration

As in the previously analyzed questions, faculty members who travel for work, have international collaborators, and faculty with who do/have neither were expected to answer the posed question differently. Their broken-down responses can be seen in Table 38.

Table 38: *The number of faculty who travel for work, have international collaborators, and those with neither experience that chose to consult secondary groups and at what stage of the implementation they were chosen to be consulted upon.*

	Travel for Work (n=6)			**International Collaborators (n=5)**			**Neither (n=5)**		
Stage	Before	During	After	Before	During	After	Before	During	After
Secondary	6	5	5	4	4	3	4	4	5
Primary Only or None	0	1	1	1	1	2	1	1	0

A Fisher's Exact test p-value of 0.8729 indicates that there is no statistical difference in responses between these groups, contrary to the hypothesis.

Just like before, traveling for work and having international collaborators was assumed to result in similar expected "gains," so the two categories were consolidated. The resulting contingency table can be seen in Table 39

Table 39: *The number of faculty who travel for work or have international collaborators and those with neither experience that chose to consult secondary groups and at what stage of the implementation they were chosen to be consulted upon.*

	Travel for Work or Have International Collaborators (n=11)			**Neither (n=5)**		
Stage	Before	During	After	Before	During	After
Secondary	10	9	8	4	4	5
Primary Only or None	1	2	3	1	1	0

A Fisher's Exact test p-value of 0.9339 indicates that there is no statistical difference in responses between these groups, contrary to the hypothesis.

While not expected, this is similar to the previously uncovered results that did not show that traveling for work or having international collaborators would change the likelihood of considering secondary groups within the implementation process.

Conclusions and Future Work

This pilot study developed a methodology for assessing chemical engineering student and faculty problem solving in the context of the global learning outcome for ABET accredited institutions. Participants' problem-solving was examined through responses to specific prompts to analyze how well they took into consideration the global factors set forth by ABET (Social, Cultural, Economic, and Environmental).

Several hypotheses were explored in this pilot study: (i) having a study abroad experience would increase the likelihood that participants included the global factors of interest, (ii) the type (PUI, Research Intensive, Unique) of institution students attended would impact how they approached the problem, (iii) the career aspirations of students would impact how they approached problem-solving, (iv) having industry experience would impact how well faculty took into consideration global factors, (v) having international collaborators or traveling for work would impact how well faculty approached the problem-solving. Additionally, problem-solving approaches of students and faculty with similar experiences were compared. No significant differences were observed in responses between groups, which was and not aligned with expectations from the literature. For instance, the students with study abroad experience were predicted to be better equipped to consider global factors than students that did not study abroad, but the statistical results did not suggest any differences between these populations. Additionally, faculty with international collaborators were expected to perform differently than those without, but this was not observed.

While the results of the pilot-scale study were limited by sample size, it does lay important groundwork for future studies in this area. To that end, there are many recommendations that can

be made for future work. A key consideration is how factors are defined. ABET does not define the terms within this learning outcome and they are largely left for self-interpretation. While ABET mentions cultural, societal, environmental, and economic competency, the organization never defines what achieving competency in any of these factors looks like. While having ill-defined outcomes bodes better for institutions creating their programs as it gives them more creative freedom with their classes, it does not lend well to analyzing the extent that the outcome is achieved. Future work would require research to collectively hone in on each factor's definition by getting a sense of how students, faculty, and engineering education experts defines the terms. Then, the definitions can be redefined based on the collective definition and the data can be reassessed or recollected. Pedagogically, if these global factors were defined, engineering education researchers may be able to find "recipes" that produce more globally minded students that can best equip institution's students for a globalized society and economy. Future work should also require survey participants to write a minimum number of words in order to improve the quality of responses.

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Appendix A: ABET's Second Set of Outcomes

1. an ability to communicate effectively with a range of audiences
2. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
3. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
4. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
5. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Appendix B: The Recruitment Email Used to Collect Participants

Dear _____,

My name is Caleb Cunningham, and I am a student at Bucknell University investigating engineering problem-solving. We are seeking participants in a research study on the task-related experiences of engineers in the workplace. I write to you in hopes that you could send the survey to your senior-year engineering students and/or your engineering faculty. This study is looking for both **faculty** and **senior-year engineering student** participation. This is being conducted by Principal Investigator Caleb Cunningham at Bucknell University and Dr. Elif Miskioğlu, Assistant Professor of Chemical Engineering at Bucknell University. This study consists of a short, 5-10 minute, survey, which will examine engineers' response to problem solving.

Participation is entirely voluntary, involves minimal risk, and has no direct benefit to you. Results will be used to develop modifications for engineering education curriculum focused on producing better-prepared professional engineers.

More information on the study is provided in the first page of the survey, which can be accessed here:

Research Study Link

Should you have questions or concerns at any time about the study and its procedures, please feel free to reach out to any member of the research team:

Caleb Cunningham
Principal Investigator
Bucknell University, Engineering
caleb.cunningham@bucknell.edu

Dr. Elif Miskioğlu
Assistant Professor
Bucknell University, Engineering
elif.miskioglu@bucknell.edu

For general questions regarding the rights of human subjects in research, please reach out to the chair of the coordinating Institutional Review Board, Matthew Slater of Bucknell University, at matthew.slater@bucknell.edu or 570-577-2767.

Thank you for your time,
Caleb Cunningham

Appendix C: ASEE Newsletter Call for Participation

CALL FOR PARTICIPATION: Brief Survey on Engineering Problem-Solving

I am a student researcher at Bucknell University studying how different populations of chemical engineers (senior undergraduate students, faculty, and industry professionals) approach problem-solving.

We are asking individuals in the chemical engineering community to participate in an online survey and answer a short prompt. The survey will take approximately 5-10 minutes to complete. Answers will remain completely confidential and be deidentified prior to dissemination.

Please click the link below for more information, including informed consent, and to begin the survey:

https://bucknell.co1.qualtrics.com/jfe/form/SV_cNsUKgIPPNATpEp

We also ask that you share this survey with others as appropriate.

For questions, please contact PI Caleb Cunningham (caleb.cunningham@bucknell.edu) or advisor Elif Miskioglu (elif.miskioglu@bucknell.edu). Please forgive duplicate postings as we try to reach our target audiences.

Appendix D: Summary Table for the question "What important factors will you consider in your design and why?"

Table D1: *The summary of p-values as well as the populations being compared for the first question "What important factors will you consider in your design and why?" Additionally, the hypothesis of whether the groups were predicted to be statistically different or not is included.*

Populations Being Compared			**Hypothesis**	**p-value**
Students that studied abroad (n=6)	International student (n=2)	Neither (n=15)	Different	0.8921
Faculty that traveled for work prior to becoming a faculty member or had a study abroad experience (n=11)	Neither (n=5		Different	0.9355
Faculty that traveled for work prior to becoming a faculty member or had a study abroad experience (n=11)	Students that studied abroad (n=6)		Not Different	0.0044
Students at a PUI (n=4)	Students at a research intensive institution (n=18)	Students at a unique institution (n=1)	Different	0.4851
Students aspiring to enter industry (n=17)	Students planning on attending graduate school (n=4)	Students with other career aspirations (n=2)	Different	0.6760
Faculty (n=16)	Students planning on attending graduate school (n=4)		Not Different	0.8812
Faculty with industry experience (n=10)	Faculty without industry experience (n=6)		Different	0.8336
Faculty that travel for work (n=6)	Faculty with international collaborators (n=5)	Faculty with neither experience (n=5)	Different	0.6665
Faculty that travel for work or	Faculty with neither		Different	0.9204

have international collaborators (n=11)	experience (n=5)			

Appendix E: The Summary Table for the question "Who would you include on your design team?"

Table E1: *The summary of p-values as well as the populations being compared for the first question "Who would you include on your design team?" Additionally, the hypothesis of whether the groups were predicted to be statistically different or not is included.*

Populations Being Compared			**Hypothesis**	**p-value**
Faculty (n=16)	Students (n=23)		None	0.4795
Students with a study abroad experience or international students (n=8)	Students with neither experience (n=15)		Different	0.4439
Faculty that traveled for work prior to becoming a faculty member or had a study abroad experience (n=11)	Faculty with neither experience (n=5)		Different	0.548
Faculty that traveled for work prior to becoming a faculty member or had a study abroad experience (n=11)	Students with a study abroad experience or international students (n=8)		Not Different	0.9259
Students at a PUI (n=4)	Students at a research intensive institution (n=18)	Students at a unique institution (n=1)	Different	0.1834
Students aspiring to enter industry (n=17)	Students planning on attending graduate school (n=4)	Students with other career aspirations (n=2)	Different	0.9846

Faculty (n=16)	Students planning on attending graduate school (n=4)		Not Different	0.5485
Faculty with industry experience (n=10)	Faculty without industry experience (n=6)		Different	0.4906
Faculty that travel for work (n=6)	Faculty with international collaborators (n=5)	Faculty with neither experience (n=5)	Different	0.4989
Faculty that travel for work or have international collaborators (n=11)	Faculty with neither experience (n=5)		Different	0.7953

Appendix F: Summary Table for the question "What individuals or groups would you want to discuss your work with before, during, and after the implementation?"

Table F1: *The summary of p-values as well as the populations being compared for the first question "What individuals or groups would you want to discuss your work with before, during, and after the implementation?" Additionally, the hypothesis of whether the groups were predicted to be statistically different or not is included.*

Populations Being Compared			**Hypothesis**	**p-value**
Faculty (n=16)	Students (n=22)		None	0.1372
Students that studied abroad (n=5)	International student (n=2)	Neither (n=15)	Different	0.6705
Students with a study abroad experience or international students (n=7)	Students with neither experience (n=15)		Different	0.5666
Faculty that traveled for work prior to becoming a faculty member or had a study abroad experience (n=11)	Faculty with neither experience (n=5)		Different	1.000
Faculty that traveled for work prior to becoming a faculty member or had a study abroad experience (n=11)	Students with a study abroad experience or international students (n=7)		Not Different	0.7699
Students at a PUI (n=3)	Students at a research intensive institution (n=18)	Students at a unique institution (n=1)	Different	0.6577

Students aspiring to enter industry (n=16)	Students planning on attending graduate school (n=4)	Students with other career aspirations (n=2)	Different	0.3885
Faculty (n=16)	Students planning on attending graduate school (n=4)		Not Different	0.0652
Faculty with industry experience (n=10)	Faculty without industry experience (n=6)		Different	1.000
Faculty that travel for work (n=6)	Faculty with international collaborators (n=5)	Faculty with neither experience (n=5)	Different	0.8729
Faculty that travel for work or have international collaborators (n=11)	Faculty with neither experience (n=5)		Different	0.9339

Appendix G: Institutions Sorted by Research Intensive, PUI, or Unique

Table G1: The institutions where responses were received sorted by whether they were deemed research intensive, PUI, or a unique institution.

Institution	Type
Bucknell University	PUI
Clarkson University	PUI
Case Western Reserve University	PUI
Missouri University of Science and Technology	Unique
Kansas State University	Research Intensive
Ohio University	Research Intensive
University of Southern California	Research Intensive
University of Oklahoma	Research Intensive
University of Illinois Urbana-Champaign	Research Intensive
University of Maine	Research Intensive
University of California Los Angeles	Research Intensive
Colorado School of Mines	Research Intensive
University of Iowa	Research Intensive
University of Idaho	Research Intensive
Oregon State University	Research Intensive
Ohio State University	Research Intensive
University of Mississippi	Research Intensive
University of Toledo	Research Intensive
Louisiana State University	Research Intensive