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Integrating the Humanities with Engineering through a Global Case Study Course

Cover Page Footnote

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Introduction

As the world becomes more connected and globalized, the problems that engineers are called upon to solve are increasingly complex and interdependent. Research on engineering work has suggested that professional engineers address open-ended, ill-structured problems that are situated in specific contexts (Bornasal et al., 2018; Stevens et al., 2014). Unfortunately, engineering coursework has traditionally focused on abstract and closed-ended problem solving, offering few opportunities for students to develop these skills (Jonassen, 2014). The unique, situated contexts of engineering problems and projects require that engineers think and work across a wide range of cultural, disciplinary, and organizational differences (Jesiek et al., 2015, 2017). This ability can be described using the theoretical framework of systems thinking, which emphasizes the need to consider both technical and contextual variables when solving problems (Grohs et al., 2018). Prior research has found that many students and engineers are not prepared to apply systems thinking in engineering projects (Mosyjowski et al., 2020), but that systems thinking can be developed via exposure to complex systems and similar interventions (Peterson et al., 2018). Building on this prior work, our project explored whether integrating engineering with the humanities could help students develop a better understanding of contextual influences in engineering work as operationalized through the lens of systems thinking.

In this practice paper, we argue for the importance of integrating the humanities and engineering to understand the multiple and intersecting layers of context in an engineering project. We then describe the *Humanities-Informed Engineering Projects* course, which we developed to help students acquire this perspective. The course was piloted in Spring 2021 in response to the obstacles to international and community engineering experiences caused by the COVID-19 pandemic. Lastly, we share preliminary assessment data on the development of systems thinking over the course. This pedagogical description and assessment project contributes to the understanding of the development of systems thinking and it also provides empirical evidence about the potential benefits of integrating the humanities and engineering in the classroom (Edmondson et al., 2020; Hynes & Swenson, 2013; Pavlica et al., 2020).

Relevant Literature

We begin by arguing for the importance of integrating humanities-based perspectives within engineering work. We then present a framework for understanding humanities in engineering projects and suggest systems thinking as way to describe and assess the skills that students develop through studying engineering with a humanities lens.

Integrating the Humanities and Engineering

Engineering is a field of study that applies science, mathematics, and technology to the existing world. As an applied field, it is inherently connected to the human experience in a variety of ways, and thus requires a multidisciplinary approach (Exter et al., 2017; Hynes & Swenson, 2013; Pavlica et al., 2020). The humanities provide understanding of the human experience, as explained in the National Foundation on the Arts and the Humanities Act (1965), which defines the humanities as:

> The study and interpretation of [...] language [...]; linguistics; history; jurisprudence; philosophy; archaeology; comparative religion; ethics; the history, criticism, and theory of the arts; those aspects of social sciences which have humanistic content and employ humanistic methods; and the study and application of the humanities to the human environment with particular attention to reflecting our diverse heritage, traditions, and history and the relevance of the humanities to the current conditions of national life.

Building an understanding of these fields into engineering can lead to a wide range of potential benefits. On an intellectual level, experience with humanities topics and methods can lead to intellectual flexibility (Shumway, 2017) and deeper understanding of current problems and possible solutions faced by engineers and other professionals (Kitch, 2017). Developing a humanities-based perspective can also practically support engineering design work, informing professionals' abilities to solve social problems (Benneworth, 2015), their ability to consider unintended consequences of engineering projects (Fila et al., 2014), and their preparation to be an engineer who works for people and with people (Hynes & Swenson, 2013). Otsuki (2018) advocates for an understanding of the intersection between the humanities and STEM because it is at this intersection where new knowledge and products are created. Lastly, humanities education can have positive effects on other professional skills such as communication, interpersonal, and intercultural skills (Edmondson et al., 2020; Pavlica et al., 2020). For all of these reasons, integrating humanities topics and approaches can enhance the engineering curriculum.

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Framework for Humanities and Engineering Integration

Hynes and Swenson (2013) provide a framework defining the intersection between engineering and the humanities. This framework describes two perspectives through which to view the connections between engineering and the humanities: *engineering for people* and *engineering with people*. Fila et al. (2014) add an additional perspective to the framework: *engineering as people*. The *engineering for people* perspective highlights the broadening group of people who are impacted by an engineer's work, from individuals to communities to nations to the world. The *engineering with people* perspective focuses on engineers' work within diverse teams and across diverse stakeholders, including the consideration of unique individuals, teams, corporations, and multinational corporations and governments (Hynes & Swemson, 2013). The *engineering as people* perspective addresses the need for engineers to understand their own identities, knowledge, skills, beliefs, and values (Fila et al., 2014). Because of the variability in the human experience and the need to consider human factors ranging from the level of individuals to global dynamics, Hynes and Swenson (2013) assert that "the humanistic aspects of engineering make engineering quite difficult to practice" (p. 32). Understanding *engineering for*, *with, and as people* is a useful framework to help students and engineers consider the intersections between humans and engineering.

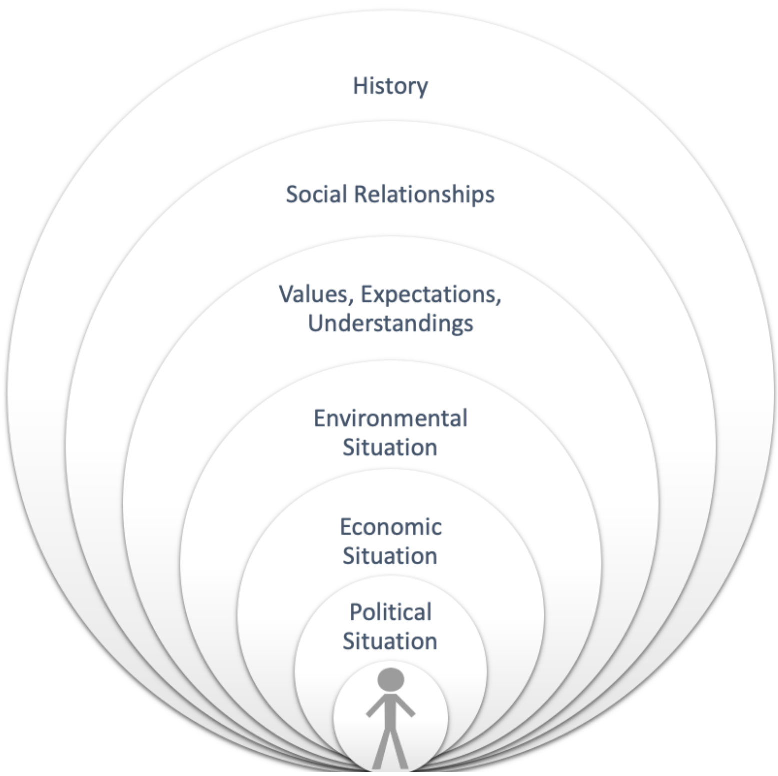

Figure 1. Understanding the context of engineering problems via the humanities

Our project builds on this existing framework to focus on the need to consider context within engineering work. We suggest that when considering any type of human-engineering interaction, engineers must understand the context in which their project is situated, including influences at the levels of the individual, community, corporation, nation, government, etc. When focusing on a given population's connection to an engineering project, engineers must have highly specialized information about the specific population within the local and global context to accurately incorporate a contextual analysis into their thinking about the problem. Hynes & Swenson (2013) and Fila et al. (2014) perhaps allude to this notion when they address the need for the humanities, but the concept requires clarification if it is to be implemented in pedagogical initiatives. Figure 1 demonstrates how humanities factors (shown in each circle) are specific to a given human or human group (e.g., individual, community) and that these factors intertwine to create the context of an engineering problem. The humanities areas of study listed in Figure 1 are not a complete list, but they provide the idea of the various knowledge sets that an engineer may need to understand the context. Furthermore, the areas of study listed are not in any special order, as specific situations may require the understanding of some topics while other situations require different topics. This understanding of context informed the design of the humanities-informed engineering course that is the focus of our project.

Student Learning through Humanities and Engineering Integration

Although there is theoretical support for the interdisciplinary study of the humanities and engineering, along with examples of programs or courses that incorporate both, there is limited research exploring the impact of such an integration on student learning (Hynes & Swenson, 2013). As a notable exception, Hynes and Swenson (2013) analyzed video-recorded data of classroom interactions and were able to point to moments during which students engaged with humanistic ideas, such as epistemologies, sociological norms, or the personal value systems of individuals, as these ideas interacted with engineering problem-solving. They argue that the examples that blend the humanities with engineering demonstrate that "inclusion of authentic opportunities to consider clients' needs and attributes while engineering can benefit students' engineering abilities and knowledge as well as their views toward engineering" (p. 38). At the university level, Exter et al. (2017) examined a program that jointly addressed technical knowledge and non-technical knowledge through having courses taught by faculty from multiple disciplinary backgrounds. The program's laboratory design courses exposed students to complex problems that required the application of multiple skills across fields of study. The authors report various barriers to achieving their transdisciplinary goal, but no empirical data on student learning. In another pedagogical intervention, Madden et al. (2013) reported on the development of a multidisciplinary program across the arts, humanities, and STEM to develop creative and innovative skills. Their goal was to provide a model of a program but they did not provide assessment data. In our project, we seek to overcome this limitation in the literature by assessing students' systems thinking skills within our humanities-informed engineering course.

We chose systems thinking skills as the focus of our assessment because we believe that this construct describes a learning outcome that we anticipate through the integration of engineering and the humanities. Systems thinking is the ability to see the world as a complex interconnected system where different parts can influence each other (Senge, 2006; Sterman, 2000). In engineering education specifically, several characteristics have been suggested as part of the skillset broadly described as systems thinking. A central component of systems thinking is the ability to connect the technical and contextual aspects of a problem (Grohs et al., 2018; Mazzurco & Daniel, 2020; Mosyjowski et al., 2020), where the contextual aspects relate to a wide range of social, cultural, economic, political, and environmental issues, among others. Incorporating stakeholder perspectives is the second characteristic of a systems thinker; it is important to consider a range of stakeholder perspectives and involve them in the problem-solving process (Grohs et al., 2018; Mazzurco & Daniel, 2020). Understanding a system also requires thinking about the influence of time (Grohs et al., 2018). For example, when proposing a solution, it is important for engineers to consider the history of the problem and attempted solutions, as well as the history of the stakeholders. Time considerations also prompt reflection on potential unintended consequences in the future (Grohs et al., 2018) and the consideration of delays between actions and their results (Meadows, 2008; Sterman, 2000). All of these components of systems thinking align with the idea of understanding context that we believe is central to the integration of engineering and the humanities (as shown in Figure 1).

Previous research has shown that while engineering students may focus on technical aspects of engineering challenges rather than contextual variables (Marzzurco & Daniel, 2020), systems thinking is a skill that can be developed through experience or intervention. One recent study found that engineering students were more likely to focus on the technical aspects of a humanitarian engineering problem compared to expert engineers who thought more broadly about both technical and contextual aspects (Mazzurco & Daniel, 2020). Another research study by Koral Kordova et al. (2018) indicated that years of employment did not correlate with scores on the Capacity for Engineering Systems Thinking (CEST) assessment measure (Frank, 2010). The study also found that graduate students in the multidisciplinary field of industrial engineering and management scored higher on the CEST measure compared to graduate students in machines engineering or psychology. The authors proposed that multidisciplinary work experiences may have led to enhanced capacity for systems thinking among the industrial engineering and management group. Finally, based on interviews with engineers and engineering students with varying levels of experience, Mosyjowski et al. (2020) characterized four different approaches to systems problems: no systems thinking, only technical, only contextual, and comprehensive (both). Taken jointly, these studies suggest that relevant expert experiences or practice with multidisciplinary approaches may lead to systems thinking. This prior work supported our belief that systems thinking was a construct that could describe student learning that results from the integrated examination of the humanities and engineering.

Background to Course Development

In this pedagogical project, we developed a one-credit course entitled *Humanities-Informed Engineering Projects*. The course is one outcome of a long-standing relationship between a global engineering program (GEARE) within the Office of Professional Practice and the School of Languages and Cultures (SLC) at Purdue University. The GEARE program is a comprehensive global engineering training program. It provides students an opportunity to integrate language study, academic exchange abroad, intercultural coaching, domestic and international professional experiences in the form of industry or research internships, and a collaborative global design team project into the traditional four-year curriculum. Students in the GEARE program specialize in a language other than English, and they complete a minimum of 12 credits (4 semesters) in their chosen language before going abroad in the Spring semester of their junior year. Upon completion, students in the program earn a Global Engineering Studies Minor.

The relationship between the GEARE program and SLC began because of a shared interest in the global world. Faculty support for GEARE has come from the engineering disciplines and SLC, considering that language and intercultural training are fundamental components of the engineering program. The goals of the cross-disciplinary team have included enhancing the preparation of global engineers through the study of languages and cultures and facilitating paths to dual degrees (i.e., Engineering and Languages and Cultures). Building on years of prior collaboration and with the support of the National Endowment for the Humanities, administrators and faculty members across the disciplines created curricular plans to integrate the humanities and engineering. Within this effort, the current course was planned with the support of a key faculty member who taught courses on Spanish for the Professions in SLC and who also had 29 years of experience as a practicing engineer in global engineering companies.

In response to the COVID-19 pandemic that affected the world beginning in Winter 2019, engineering students' global internships were canceled from Spring 2020 to the time of writing this article. With the absence of these internships, there was an increased need for students to gain practical and global experiences and also exposure to complex, situated engineering problems without traveling, leading us to accelerate the timeline for offering *Humanities-Informed Engineering Projects* to Spring 2021. The course was offered by the School of Languages and Cultures (SLC); SLC faculty members led the development of the course with support from the Engineering team. Two sections were offered: one taught in English and the other in Spanish. This was to accommodate students with different career goals and language proficiencies. The project team plans to offer the course each Spring semester and expand the offering to include a section taught in German. Regarding the fit within students' plans of study or degree plans, the course has been incorporated into the array of intercultural academic activities that GEARE students must fulfill during their sophomore year as part of the required intercultural seminars and activities. It is also an elective course within the major and minor plans in SLC. While the target student population is that of the GEARE program, any student who has the technical engineering skills and language proficiency (e.g., Spanish for the Spanish section) needed to participate in the course may enroll.

Course Description

The *Humanities-Informed Engineering Projects* course aims to provide students with the opportunity to examine complex engineering problems and solutions. Students analyze engineering case studies from a humanistic–engineering perspective, in which the humanities are presented as a lens for understanding context, given that the humanities (e.g., arts, culture, history, language, philosophy, politics, sociology) encourage analysis and critical thinking about all aspects of the human world and experience as well as their interconnections. Case studies are a pedagogical approach that presents problem scenarios to help students understand engineering problems in context. These scenarios typically focus on real-life events, present both contextual and technical information, and do not offer a clear-cut solution (C. Davis & Yadav, 2014). Case studies have been cited as a good option for helping students learn to address complex and ill-structured problems, especially given that they do not suggest a single approach to understanding or solving such problems (Jonassen, 2014). Prior studies have explored the use of case studies to teach ethics reasoning (e.g., Hess et al., 2017), global project management (e.g., Rectanus, 2013), and other professional skills. Because of these characteristics of case studies and their utility in pedagogical settings, we believe that case studies have strong potential as a strategy for integrating the humanities with engineering in a meaningful way.

The course objectives were designed considering the need for engineers to incorporate technical and contextual aspects into their understanding of engineering problems and solutions. Course objectives are: (1) discuss various approaches to engineering problems in class meetings or online discussion boards; (2) analyze global engineering problems from engineering and humanistic perspectives as evidenced in written case study responses, quizzes, and other assessments; (3) explain the application of humanistic fields of study to engineering problems via a final course assessment; and (4) use Spanish language skills (vocabulary and grammar) related to the professional topics of the course (for the Spanish language section). The course calendar and organization of the course were structured around case study modules. The case studies included past, present, and hypothetical engineering projects, and they addressed a range of technical and contextual topics specific to given engineering problems (Table 1). The section of the class taught in English examined case studies in more varied locations in the world (i.e., case studies 1–6, Table 1), and the section taught in Spanish focused on case studies in the Spanish-speaking world (i.e., case studies 3, 6–8, Table 1). The Spanish section included fewer case studies compared to the English section because learning in a second language requires additional effort, and the Spanish section also includes additional language learning objectives.

For each case study module, lasting 2–3 weeks, students completed a series of individual and group activities that required engineering skills in addition to consideration of the perspectives of local community stakeholders and the context (i.e., sociological, anthropological, cultural, and historical information and analyses). Before classes, students learned new information through written or audio materials and assessments. These readings and other activities were developed based on news sources, government websites, and academic publications that addressed issues related to the individual case. During class, students learned about new, related content to further consider the case's context, and they analyzed different perspectives made available through the new content. They also completed short writing assignments and participated in online discussion boards with classmates to further analyze and synthesize new material introduced during in-class meetings, which added complexity to their understandings of the cases and their contexts.

Table 1. Case study locations and technical and contextual topics by course section

	Case study	Technical topics	Cultural and social topics
1	**Water Barriers: Venice, Italy**	• Construction system; architecture • Water barriers • Project MoSE - Venice	• Culture, art, music, literature: Europe vs. the USA • Venetians — flooding as part of their life; social and economic impacts • Culture heritage vs. the environment
2	**Hyperloop: Europe and USA**	• Trains • Resistance, friction, magnetic levitation • Hyperloop components • Standardization in Europe and the USA	• Transportation and society • Transport systems as a component of society • Transportation: changes in behavior, culture, and landscapes
3	**Wind farms: Jepírachi, Colombia**	• Wind farms • Construction system • Civil and electrical infrastructure	• Technology vs. culture and traditions • How technology affects culture • Negotiations with minority groups: indigenous/native people • Renewable energy and its impacts on communities
4	**Belt and Road: China**	• Infrastructure: ports, roads, railways • Big data • Artificial Intelligence	• Cultural differences and barriers: China and other involved countries • Economic impacts • Document: *Cultural Perspective of China's BRI: Impacts, Insights, and Implications*
5	**Dam removal: Portes, France**	• Dams • Techniques to remove dams	• Resettlement • Dams and the environment; salmon migration
6	**Photovoltaic and hybrid systems: Galapagos Islands, Ecuador**	• Photovoltaic design criteria	• Document: *Cultural Patterns for Sustainability in Galapagos Society* • Tourists and tourism vs. sustainability
7	**Mining: Ciudad de Potosí, Bolivia**	• Construction of mines • Mineral extraction techniques • Improvement of mine conditions	• Traditions and the impact of mining on the city and the society • Child labor in mines
8	**Incan Construction: Machu Picchu, Perú**	• Incan construction techniques • Methods to lift and move heavy objects with pulleys and ropes	• The Inca of the past: their culture and traditions • The impact of tourism on the city

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In the example of the *Wind farms: Jepírachi, Colombia* case study (see Appendix A for a summary of the curricular plan), students read the introductory case study to learn about the problem, community, and specific technical and contextual considerations before class. They completed an online quiz following the reading and in preparation for the first class meeting. In the first class, they participated in language learning in the Spanish section and both sections of students analyzed the interrelations among the different stakeholders and stakeholder goals, considering specifically the location and cultural norms of the Wayúu people, a native indigenous group in northeast Colombia and northeast Venezuela. For this case study, the second class meeting focused on humanities-oriented understandings of culture and context, technical understandings of various engineering projects that relate to wind farms, and the potential consequences of a singular focus on traditional engineering project goals (i.e., maximize production, minimize costs, legal regulations). The class discussed the potential failures of not incorporating humanities-oriented perspectives, such as adverse environmental and cultural outcomes for the local communities. In the third and final class meeting focused on the wind farm project, students synthesized what they had learned about the case, and they roleplayed negotiations between stakeholder groups in small groups. To draw each case study to a close, students completed a final written assignment in which they analyzed certain aspects of the case, providing possible solutions and potential impacts while also considering the perspectives of different stakeholders and communities. The final assignment related to the *Wind farms: Jepírachi, Colombia* case study included essay questions requiring synthesis of technical and contextual considerations and a role-play scenario to help students envision the actual work of an engineer who interfaces with a variety of diverse stakeholders (Appendix B).

For all case studies, the curricular plan encouraged students to learn independently in preparation for class and demonstrate what they had learned through various types of assessments (e.g., online quiz, written assignment, discussion board interactions). Class time was used to add new perspectives to the analysis of the individual cases and highlight aspects of the intersection between technical and contextual considerations, greatly relying on small group discussions, guided analyses, or practical applications. The course relied on a flipped classroom structure, which is the norm in second language classrooms, to facilitate students' preparation to engage with class materials before class and engagement with new ideas through work with other students during class. The pedagogical approach blended humanities-oriented knowledge and critical analyses along with technical engineering knowledge and skills. This approach and structure led to analyses, ideas, and perspectives that were unique to the individual groups of learners.

Assessment Approach

To assess the initial offering of the *Humanities-Informed Engineering Projects* course, we used a scenario-based assessment of systems thinking known as the village of Abeesee scenario (Grohs et al., 2018). As discussed above, we view systems thinking as a likely student learning outcome when integrating the humanities with engineering, so our assessment approach emphasized this outcome. However, it is important to note that the course was not designed specifically for the development of systems thinking constructs in students. Now that we have begun to explore this connection, future iterations of the course will more intentionally build on the systems thinking framework we present here.

We chose an existing scenario-based assessment of systems thinking because these approaches allow for more nuanced data collection than typical Likert-scale surveys. At the same time, because the scenario was developed with a scoring rubric, the assessment was practical to analyze compared to more open-ended qualitative data such as interviews or reflections. We selected the village of Abeesee scenario, which was developed by Grohs et al. (2018), because it assesses multiple dimensions of systems thinking and provides detailed rubrics along with clear instructions for scoring student responses. The students also completed short reflections at the end of the semester, which we used to support the interpretation of the scenario results, but we did not do an in-depth analysis of this data source. The purpose of this assessment was to determine whether the students' systems thinking skills improved during the semester when they took the course.

Data Collection

The village of Abeesee scenario is a scenario-based assessment developed by Grohs et al. (2018) which describes the challenges faced by residents of a fictitious village during the winter (Figure 2). After reading the scenario, respondents are presented with a series of eight open-ended questions to elicit their analysis of different aspects of the situation (the list of questions is included in Appendix C). Most responses to these questions are two to five sentences in length. This assessment tool was developed based on the Dimensions of Systems Thinking Framework with the goal of challenging respondents to demonstrate systems thinking by considering a set of information, defining a problem, developing decision-making and implementation processes, and creating and evaluating potential situational solutions (Grohs et al., 2018). The responses are scored according to a series of rubrics based on seven constructs that fit within the framework. The constructs and their definitions are shown in Table 2. For the detailed rubrics and a full description of the scenario development process, see Grohs et al. (2018).

Problem statement for the village of Abeesee:

The Village of Abeesee has about 50,000 people. Its harsh winters and remote location make heating a living space very expensive. The rising price of fossil fuels has been reflected in the heating expenses of Abeesee residents. In fact, many residents are unable to afford heat for the entire winter (5 months). A University of Abeesee study shows that 38% of village residents have gone without heat for at least 30 winter days in the last 24 months. Last year, 27 Abeesee deaths were attributed to unheated homes. Most died from hypothermia/exposure (21), and the remainder died in fires or from carbon monoxide poisoning that resulted from improper use of alternative heat sources (e.g., burning trash in an unventilated space).

Figure 2. Village of Abeesee scenario (reproduced from Grohs et al., 2018)

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Table 2. List of systems thinking constructs (Grohs et al., 2018)

Construct	Definition
Problem Identification	Refers to a respondent's ability to describe perceptions of the problems and/or issues facing Abeesee
Information Needs	Refers to a respondent's ability to identify additional context/information beyond the details provided in the scenario that is needed to address the problem identified
Stakeholder Awareness	Refers to a respondent's ability to identify and include relevant stakeholders and the role that they will play in the problem and solution identification, planning, and implementation process
Goals	Refers to a respondent's ability to identify short- and long-term goals towards addressing the problems and/or issues of the scenario
Implementation Challenges	Refers to a respondent's ability to identify expected barriers to their crafted response to the Abeesee scenario
Unintended Consequences	Refers to a respondent's ability to demonstrate flexibility in being self-critical and identifying possible blind spots of an attempted solution and the degree to which a respondent explored possible limitations and unintended consequences
Alignment	Refers to the degree to which a respondent incorporates aspects of the problem identified in responses to goals and plans

The study was approved by the Purdue University IRB. We administered the village of Abeesee scenario assessment in the first week and last week of the *Humanities-Informed Engineering Projects* course during the Spring 2021 semester. There were 19 undergraduate students enrolled across both sections the course (Spanish – 8, English – 11), representing a range of engineering majors (Chemical–6 students, Mechanical–5, Civil–3, Materials–2, Electrical–1, Aeronautical and Astronautical–1, and Computer–1) and levels of academic experience (Fourth Year–5, Third Year–11, Second Year–3). In terms of cultural experiences, four students had study abroad or internship experiences abroad, and 17 students reported using a language other than English, which was reported to be a native language of all students. The languages used by these students other than English included: German–7, Spanish–7, French–2, Japanese–1, Portuguese–1. The students completed the scenario via an online survey.

In addition to again completing the systems thinking assessment at the end of the semester, students were asked to complete a written reflection assignment where they compared their pre-course and post-course responses to the village of Abeesee scenario. They also reflected on what they had learned during the course in response to a series of questions. The research team analyzed the student responses to the following prompt to further understand student learning in the course:

> *Please examine your Village of Abeesee Scenario critical thinking task from the beginning and end of the semester. Compare your responses for each of the two activities.*

- *What similarities and differences, if any, do you notice between your responses?*
- *Why do you think there were differences in responses between the start and end of the semester? What has changed between now and then?*

We chose to review students' responses to this reflection to help us understand how they had experienced the scenario assessment and interpret their scenario responses.

Data Analysis

We deidentified the students' responses to the scenario assessment before scoring. The scoring process was completed by four members of the research team using the scoring rubrics and instructions provided by Grohs et al. (2018) in their paper on the development of this assessment tool. Every response was scored separately by two team members who then met to discuss ratings and reach a final agreement. In scoring the pre-course test responses, the entire team met after scoring a few responses to discuss and reach an agreement regarding the terminology in the rubric (including referencing the instructions from the original paper for guidance). On average, the raters agreed in their initial scoring 68% of the time, but 100% agreement was achieved by meeting together and reviewing responses for which initial scores did not align.

Once the scenario scores were finalized, we compared the mean scores between the pre-course and post-course responses for each construct. We then conducted a paired *t*-test analysis for each construct to determine if there was a statistically significant change between the start and end of the semester. To check for normality of the data, we considered the skewness and kurtosis of the difference between pre-test and post-test values (Field et al., 2012). The absolute skewness and absolute kurtosis of this difference were below 1.0 and 2.0 respectively, indicating that our data were sufficiently normal for this analysis (Krathwohl, 2009). Because Cohen's *d* can overestimate effect size for small samples, we calculated Hedges's *g* instead, which corrects for this upward bias (Turner & Bernard, 2006).

To help with our interpretation of the scenario assessment results, we decided it would be helpful to consider students' reflections on their scenario responses. Because this was an initial offering of the course and our first time using this assessment instrument, we specifically wanted to know whether the students' perceptions of their learning aligned with their scores on the instrument. To address this question, two members of the research team reviewed the student responses to the reflection prompt and scored them based on which of the systems thinking constructs (from Table 2) the students discussed in their reflections. Each reflection was scored as either "better" (the student felt they had improved on a construct), "same" (the student felt there was no change), or "N/A" (the student did not mention this construct). The two researchers scored the reflections independently, met to discuss, and came to an agreement about the scores. We did not conduct a more thorough analysis of the reflections at this time, as the purpose of this analysis was to support our understanding of the scenario results.

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Limitations

This practice paper is intended to introduce the reader to the pedagogical approach we have developed through the *Humanities-Informed Engineering Projects* course. The assessment results provide support for our design, but are limited in scope because of the small sample size available in the first iteration of the course. As a result, our assessment results cannot be generalized, although aspects of our findings may be transferrable to other contexts where educators are endeavoring to integrate engineering with the humanities. Additionally, although t-tests can be conducted for sample sizes less than 20, it is preferable to have a larger sample size. In this case, we provide the t-test results but draw our main conclusions from the differences in means between the pre-and post-tests. Finally, we inadvertently left one of the questions off of the pre-test, so we were unable to compare scores on the *Unintended Consequences* construct.

Assessment Results

The purpose of this paper is to introduce the *Humanities-Informed Engineering Projects* course as an approach to integrating humanities and engineering. We have identified systems thinking as a key outcome of this type of curricular integration and in this section, we present the results of our assessment of systems thinking development in the students from the first offering of this course. We begin by presenting the t-test results comparing students' scores on the Abeesee scenario from the beginning and end of the course. We then use the students' end-of-course reflections on their scenario responses to help interpret the t-test results and explore in more depth how students responded to the scenario.

Comparison of Pre- and Post-Course Test Scenario Scores

Between the pre-and post-course tests, the average score increased for three systems thinking constructs: *Information Needs*, *Goals*, and *Alignment*. In contrast, the scores for *Stakeholder Awareness* and *Implementation Challenges* declined between the start and end of the semester, and the *Problem Identification* scores were constant. The changes in average scores were between one quarter to one half of a point (in both directions), which is a practically significant change given that the rubrics use a four-point scale (ranging from 0–3). We conducted t-tests to further compare the pre- and post-course test scores and found that the change was statistically significant for three constructs ($p < .05$). These results are shown in Table 3.

Analysis of Student Reflections

The end-of-course reflections asked students to compare their pre- and post-course responses to the Abeesee scenario. We reviewed these reflections to see which constructs of systems thinking (Table 2) students discussed in their reflections to determine whether their assessment of their work aligned with the scoring based on the rubrics. Table 4 summarizes our findings and shows whether students felt they did the same, better, or did not comment on each construct. We discuss two constructs in more detail to provide examples of the types of reflections students provided. These two constructs are *Information Needs*, the construct for which the most students identified improvement, and *Stakeholder Awareness*, the construct for which the least number of students identified improvement.

Table 3. Comparing pre-test and post-test scenario scores (scale of 0-3)

		Pre-Test		Post-Test					
Construct	**df**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Diff**	***t***	***p***	***Effect Size****
Problem Identification	18	1.53	0.68	1.53	0.68	0.00	0.00	.500	0.00
Information Needs	18	1.74	0.71	2.11	0.43	**0.37**	1.79	.045	0.53
Stakeholder Awareness	18	1.58	0.88	1.16	0.92	*-0.42*	-1.80	.044	-0.45
Goals	18	1.95	0.51	2.21	0.41	**0.26**	1.42	.086	0.56
Implementation Challenges	18	2.05	0.69	1.68	0.65	*-0.37*	-1.79	.045	-0.54
Alignment	18	1.68	0.73	1.95	0.89	**0.26**	1.16	.131	0.32

Notes: Green & bold cells = increase from pre- to post-course test. Orange & italic cells = decrease from pre- to post-course test.
*Effect Size measured using Hedges's *g*.

Table 4. Systems thinking constructs in student reflections

	Problem Identification	**Information Needs**	**Stakeholder Awareness**	**Goals**	**Implementation Challenges**	**Alignment**
Better	7	10	5	9	8	1
Same	7	3	6	6	3	0
N/A	5	6	8	4	8	18

Information Needs Construct. The *Information Needs* construct was the most common area where students identified improvement between their pre-course and post-course reflections. Of the 19 students, ten wrote about their improved ability to consider additional information that would support them in developing a plan. In many cases, students learned that information about the local population's cultures and viewpoints was necessary to understand the problem and propose solutions. For example, one student made the following comment:

> I wanted to know more about Abeesee culture to understand their values and beliefs to maximize the benefits they could obtain from a new idea without interfering with their culture. [...] I think that my overall action plan [...] incorporates more of a willingness to immerse myself into Abeesee culture before determining the best solution for the community.

Beyond an increased focus on learning about the local culture, students also discussed a shift in their overall analytical approaches from one that focused on solutions to one that sought a greater understanding of the problem through the incorporation of additional information. This change of mindset is described by one student this way:

> Given the information I learned throughout the semester, I changed my approach to a more [...] information gathering one. I would now look to see where systematic deficiencies are in terms of the community as a whole, the government, and the economy.

In essence, several students described how their view of the job of an engineer shifted to include information gathering as an important preliminary task in any project. Overall, the students' reflections aligned with the *t*-test results in highlighting the *Information Needs* construct as an area of growth over the course of the semester.

Stakeholder Awareness Construct. In contrast, the *Stakeholder Awareness* construct was much less likely to be mentioned by students as an area of improvement in their reflections. Only five students cited this construct as better in the post-course Abeesee response, and more than a third of students did not mention this construct at all in their reflections. At first, these results were surprising given that the case studies used in the course highlighted different stakeholder needs. However, in reading the reflections, it became clear that there could be a few reasons for this discrepancy. First, some students commented that they felt that identifying stakeholders was a process they were already aware of before taking this course. For example, one student made the following comment:

> The similarities presented in both of my responses include stating the general problem and also being aware of the importance of collaborating with other people in order to fix the problem properly.

Second, the *Stakeholder Awareness* construct as defined for our analysis focuses not simply on listing stakeholders but understanding their needs and iteratively integrating them into the problem definition and solving processes. Few students achieved this kind of thinking in either their responses or reflections, although one student provides a good example of what the rubric for this construct was looking for in the following quote:

> It is clear how taking this course influenced my response to [question about stakeholders], as my post-test reply was centered around communicating with the stakeholders and ensuring that everybody's needs were met. My pre-test response posed technical solutions before communicating with the community.

Unlike this student, most students who commented on stakeholders focused on the number or types of stakeholders identified in their responses rather than how they were integrated into the proposed plan. Overall, the student reflections aligned with the *t*-test results which suggested that the *Stakeholder Awareness* construct was not the main area of growth for students during the semester.

Discussion and Implications

In this practice paper, we have argued for the importance of integrating the humanities and engineering, outlined a course that attempts to do this, and presented initial assessment data for this course. The *Humanities-Informed Engineering Projects* course was developed as a collaboration between the School of Languages and Cultures and the College of Engineering to help students learn to think about engineering problems and solutions through the lens of the humanities. The course was built on a series of case studies to develop students' ability to consider the context in the analysis of engineering problems. Based on our approach to integrating the humanities with engineering, we identified systems thinking as an appropriate learning outcome to assess in relation to this course. Our evaluation of this initial course offering used a scenario-based assessment of systems thinking to compare students' systems thinking skills between the start and end of the semester. Our findings suggested that students in the course developed most notably in the systems thinking construct of *Information Needs*; that is, they seem to have a broader understanding of the types of information (e.g., cultural information) that would be necessary to address an engineering problem within a specific context. Students also improved in their ability to set *Goals* that considered both technical and contextual aspects of the problem and in achieving *Alignment* across their descriptions of the problem, plan, and related goals. On the other hand, we saw declines in student responses on other systems thinking constructs (i.e., *Stakeholder Awareness* and *Implementation Challenges*). We discuss these findings in terms of the learning opportunities afforded by a humanities-engineering pedagogical approach and the understanding of systems thinking that emerges.

Our findings indicate that a humanities-engineering course may offer students developmental opportunities related to the systems thinking constructs of *Information Needs*, *Goals*, and *Alignment*. Similar to the *Information Needs* results, Hynes and Swenson (2013) observed that elementary school students exposed to a humanities-engineering pedagogical program were able to consider human-related information as it impacted the engineering endeavors. The current results, taken with Hynes and Swenson's (2013) observations, point to a potential benefit of the humanities-engineering approach, which is the ability to consider human perspectives, values, and ways of being as fundamental initiating points for understanding an engineering problem or beginning to formulate a solution. The three constructs where development was identified in the current pedagogical assessment relate to two of the three important aspects of systems thinking for engineers, namely, the ability to consider contextual and technical aspects (*Information Needs*, *Goals*) and time (*Information Needs, Alignment*) (Grohs et al., 2018). Without more prior assessment data from pedagogical projects, it is unclear whether this finding may be attributed to a humanities-engineering pedagogical approach in general or the particular approach taken in the course described. Taking any development in systems thinking as a positive finding, the current results support the notion that multidisciplinary opportunities support the development of systems thinking (e.g., Koral Kordova et al., 2018).

The decline in scores for certain dimensions of systems thinking (i.e., *Stakeholder Awareness* and *Implementation Challenges*), while not expected, provides us with the

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opportunity to reflect on the construct of systems thinking as a whole. Instead of thinking of it as a single learning outcome, the current data are best explained through acknowledging the different types of skills involved in systems thinking. It is possible that some constructs that we evaluated were more aligned with the course curriculum than others. The *Information Needs* and *Goals* constructs, for example, were topics covered in the case studies, which focused on understanding the context for each engineering problem. In contrast, the *Stakeholder Awareness* and *Implementation Challenges* constructs are more closely tied to developing solutions to problems, which was not a focus of this course since students examined completed or in-progress engineering projects. With this explanation for the mixed findings, we interpret the course to be successful in contributing to students' development of systems thinking. The student reflections support this conclusion, where most students described a change in their thinking about how to consider the contextual elements of an engineering problem.

Broadly, our findings suggest that while students' systems thinking increased over the course, one course may not be sufficient to support student learning across all aspects of systems thinking and that a variety of learning experiences would be necessary to develop the wide array of knowledge and behaviors associated with this concept. Mazzurco et al. (2019) drew a similar conclusion in their study of the development of socio-technical expertise within an engineering course, suggesting that more time is needed across the engineering curriculum for such expertise to be developed. Nevertheless, our study suggests that a course like *Humanities-Informed Engineering Projects* could be an important part of a larger process of engineering students developing systems thinking skills.

Implications for Practice

Traditional engineering curricula often overlook the context of the problems presented. In the *Humanities-Informed Engineering Projects* course presented in this paper, the collaboration between the School of Languages and Cultures and the College of Engineering brings the possibility to integrate language, culture, and systems thinking into engineering in a unique way. Building interdisciplinary collaborations like this can provide much needed perspectives on engineering work that can better prepare students to address complex problems. Our findings in this paper also emphasize the need for a range of experiences to develop different aspects of systems thinking, which could benefit from the support and input of different disciplinary or departmental groups on campus. For example, one earlier study highlighted how support from a library division could help improve engineering students' sociotechnical thinking (Barsky et al., 2011). More broadly, prior research has suggested that experiential learning programs such as study abroad and service-learning can support interdisciplinary thinking (Lattuca et al., 2017). In alignment with this earlier work, our study suggests that building engineering curricula that provide students with these types of opportunities could support greater development of systems thinking expertise across the different constructs we considered in this study.

We see this humanities-engineering course approach as complementary to other efforts that encourage engineering students to expand their understanding of engineering problems and solutions. For example, experiential learning opportunities such as study abroad or service learning projects also expose students to varied and diverse contexts (e.g., Bielefeldt & Pearce, 2012; K. A. Davis & Knight, 2021; Huff et al., 2016; Knight et al., 2019). These programs, while providing learning opportunities, may not be accessible for all students because of a range of reasons, including academic program constraints, socioeconomic factors, or, as in the case of the 2020–2021 academic year, global pandemics. Therefore, an at-home pedagogical option for students that provides a humanities-informed engineering approach to context and engineering problem solving is potentially useful. Furthermore, international and community-based programs have at times been critiqued for insufficiently preparing students to understand the power differential among groups (Nieusma & Riley, 2010; Schneider et al., 2009) and not providing benefits to both the students and partner communities (Schneider et al., 2009). There are also common challenges to involving the local communities when doing humanitarian engineering projects, which include communication, cultural, and ethical challenges (Mazzurco & Jesiek, 2017). In response to these issues, it is possible that additional preparation in considering the context of a technical problem (via courses like ours) would help engineers to avoid these challenges while working in diverse communities.

Conclusion

This paper reports on the first iteration of the *Humanities-Informed Engineering Projects* course, and results point to benefits of the humanities-engineering pedagogical approach. Students' increase in systems thinking constructs of *Information Needs*, *Goals*, and *Alignment* highlight the benefit of the course in terms of two of the three main aspects of systems thinking that are important for engineers, i.e., incorporation of technical and contextual aspects of the problem and also time considerations (see Grohs et al., 2018). Given the positive findings and considering the small data set, we will continue to offer the course in future semesters and we will collect additional data in future iterations of the course. We plan to continue collecting data on systems thinking skills and will seek to explore additional forms of assessment including reflections and student assignments related to the case studies. We are additionally interested in exploring systems thinking across disciplinary boundaries to understand how traditional humanities and engineering curricula may prepare students differently for this type of thinking. Given the results of the present study, we also believe it will be important to track students over a longer period to understand how a series of experiences may lead to the development of greater systems thinking expertise across different constructs.

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References

Barsky, E., Berndt, A., Greenwood, A., & Paterson, C. (2011). What information sources do engineering students use to address authentic sociotechnical problems? 2011 ASEE Annual Conference & Exposition, Vancouver, Canada.

Benneworth, P. (2015). Tracing how arts and humanities research translates, circulates and consolidates in society. How have scholars been reacting to diverse impact and public value agendas? *Arts and Humanities in Higher Education*, *14*(1), 45–60. https://doi.org/10.1177/1474022214533888

Bielefeldt, A. R., & Pearce, J. M. (2012). Service learning in engineering. In T. H. Colledge (Ed.), *Convergence: Philosophies and Pedagogies for Developing the Next Generation of Humanitarian Engineers and Social Entrepreneurs* (pp. 24–52). National Collegiate Inventors and Innovators Alliance. http://digitalcommons.mtu.edu/materials_fp/54/

Bornasal, F., Brown, S., Perova-Mello, N., & Beddoes, K. D. (2018). Conceptual growth in engineering practice. *Journal of Engineering Education*, *107*(2), 318–348. https://doi.org/10.1002/jee.20196

Davis, C., & Yadav, A. (2014). Case studies in engineering. In A. Johri & B. M. Olds (Eds.), *Cambridge Handbook of Engineering Education Research* (pp. 161–180). Cambridge University Press.

Davis, K. A., & Knight, D. B. (2021). Comparing students' study abroad experiences and outcomes across global contexts. *International Journal of Intercultural Relations*, *83*, 114–127. https://doi.org/10.1016/j.ijintrel.2021.05.003

Edmondson, J., Formica, P., & Mitra, J. (2020). Special issue: Empathy, sensibility and graduate employment – Can the humanities help? *Industry and Higher Education*, *34*(4), 223–229. https://doi.org/10.1177/0950422220928821

Exter, M., Ashby, I., Gray, C., Wilder, D., & Krause, T. (2017). Systematically Integrating Liberal Education in a Transdisciplinary Design Studio Environment. 2017 ASEE Annual Conference & Exposition, Columbus, Ohio. https://doi.org/10.18260/1-2--28901

Field, A., Miles, J., & Field, Z. (2012). *Discovering statistics using R*. Sage Publications.

Fila, N. D., Hess, J., Hira, A., Joslyn, C. H., Tolbert, D., & Hynes, M. M. (2014). The people part of engineering: Engineering for, with, and as people. *2014 IEEE Frontiers in Education Conference (FIE) Proceedings*. https://doi.org/10.1109/FIE.2014.7044106

Frank, M. (2010). Assessing the interest for systems engineering positions and other engineering positions' required capacity for engineering systems thinking (CEST). *Systems Engineering*, *13*(2), 161–174. https://doi.org/10.1002/sys.20140

Grohs, J. R., Kirk, G. R., Soledad, M. M., & Knight, D. B. (2018). Assessing systems thinking: A tool to measure complex reasoning through ill-structured problems. *Thinking Skills and Creativity*, *28*, 110–130. https://doi.org/10.1016/j.tsc.2018.03.003

Hess, J. L., Strobel, J., & Brightman, A. O. (2017). The development of empathetic perspective-taking in an engineering ethics course. *Journal of Engineering Education*, *106*(4), 534–563. https://doi.org/10.1002/jee.20175

Huff, J. L., Zoltowski, C. B., & Oakes, W. C. (2016). Preparing engineers for the workplace through service learning: Perceptions of EPICS alumni. *Journal of Engineering Education*, *105*(1), 43–69. https://doi.org/10.1002/jee.20107

Hynes, M., & Swenson, J. (2013). The humanistic side of engineering: Considering Social science and humanities dimensions of engineering in education and research. *Journal of Pre-College Engineering Education Research (J-PEER)*, *3*(2). https://doi.org/10.7771/2157-9288.1070

Jesiek, B. K., Trellinger, N. M., & Nittala, S. (2017). Closing the practice gap: Studying boundary spanning in engineering practice to inform educational practice. 2017 IEEE Frontiers in Education Conference, Indianapolis, IN. https://doi.org/10.1109/FIE.2017.8190503

Jesiek, B. K., Woo, S. E., Zhu, Q., Ramane, K. D., & Choudhary, N. (2015). Defining and assessing global engineering competency: Methodological reflections. 2015 ASEE Annual Conference and Exposition, Seattle, WA. https://doi.org/10.18260/p.23781

Jonassen, D. H. (2014). Engineers as problem solvers. In A. Johri & B. M. Olds (Eds.), *Cambridge Handbook of Engineering Education Research* (pp. 103–118). Cambridge University Press.

Kitch, S. L. (2017). How can humanities interventions promote progress in the environmental sciences? *Humanities*, *6*(4), 76–90.

Knight, D. B., Davis, K. A., Kinoshita, T., Ogilvie, A. M., & Twyman, C. A. (2019). The Rising Sophomore Abroad Program: Early experiential learning in global engineering. *Advances in Engineering Education*, *Fall*, 1–30.

Koral Kordova, S., Frank, M., & Nissel Miller, A. (2018). Systems Thinking Education—Seeing the Forest through the Trees. *Systems*, *6*(3), 29. https://doi.org/10.3390/systems6030029

Krathwohl, D. R. (2009). *Methods of educational and social science research*. Waveland Press, Inc.

Lattuca, L. R., Knight, D. B., Ro, H. K., & Novoselich, B. J. (2017). Supporting the development of engineers' interdisciplinary competence. *Journal of Engineering Education*, *106*(1), 71–97. https://doi.org/10.1002/jee.20155

Madden, M. E., Baxter, M., Beauchamp, H., Bouchard, K., Habermas, D., Huff, M., Ladd, B., Pearon, J., & Plague, G. (2013). Rethinking STEM Education: An Interdisciplinary STEAM Curriculum. *Procedia Computer Science*, *20*, 541–546. https://doi.org/10.1016/j.procs.2013.09.316

Mazzurco, A., & Daniel, S. (2020). Socio-technical thinking of students and practitioners in the context of humanitarian engineering. *Journal of Engineering Education*, *109*(2), 243–261. https://doi.org/10.1002/jee.20307

Mazzurco, A., Daniel, S. A., & Smith, J. (2019). Development of socio-technical and co-design expertise in engineering students. 2019 Research in Engineering Education Symposium (REES), Cape Town, South Africa.

Mazzurco, A., & Jesiek, B. K. (2017). Laying the foundations of a learning platform for humanitarian engineering: Methodological approach and results. 2017 ASEE Annual Conference & Exposition. https://doi.org/10.18260/1-2--28606

Meadows, D. H. (2008). *Thinking in systems: A primer*. Chelsea Green Publishing.

Mosyjowski, E. A., Espinoza von Bischhoffshausen, J., Lattuca, L. R., & Daly, S. R. (2020). Student and practitioner approaches to systems thinking: Integrating technical and contextual considerations. 2020 ASEE Virtual Annual Conference. https://doi.org/10.18260/1-2--35219

National Foundation on the Arts and the Humanities Act, Pub. L. No. 89–209, 20 U.S.C. (1965). https://www.neh.gov/about/history/national-foundation-arts-and-humanities-act-1965-pl-89-209

Nieusma, D., & Riley, D. (2010). Designs on development: Engineering, globalization, and social justice. *Engineering Studies*, *2*(1), 29–59. https://doi.org/10.1080/19378621003604748

Otsuki, G. J. (2018). Finding the humanities in STEM: Anthropological reflections from working at the intersection. In J. N. Hawkins, A. Yamada, R. Yamada, & W. J. Jacob (Eds.), *New Directions of STEM Research and Learning in the World Ranking Movement* (pp. 65–78). Springer International Publishing. https://doi.org/10.1007/978-3-319-98666-1_5

Pavlica, M., Babic, T., & Cuculic, P. (2020). Effective decision making: The added value of including humanities in STEM studies. 2020 43rd International Convention on Information, Communication and Electronic Technology (MIPRO), Opatija, Croatia, 641–647. https://doi.org/10.23919/MIPRO48935.2020.9245347

Peterson, J. E., Frantz, C. M., Tincknell, E., & Canning, C. (2018). An animated visual representation of real-time resource flows through a community enhances systems thinking. *Systems Research and Behavioral Science*, *35*, 718–737. https://doi.org/10.1002/sres.2514

Rectanus, M. W. (2013). Transdisciplinary case studies as a framework for working in global project teams. *Online Journal for Global Engineering Education*, *6*(1), 1–20.

Schneider, J., Lucena, J., & Leydens, J. A. (2009). Engineering to help. *IEEE Technology and Society Magazine*, *28*(4), 42–48. https://doi.org/10.1109/MTS.2009.935008

Senge, P. M. (2006). *The fifth discipline: The art and practice of the learning organization*. Crown Publishing.

Shumway, D. R. (2017). The university, neoliberalism, and the humanities: A history. *Humanities*, *6*(4), 83–92.

Sterman, J. D. (2000). *Business dynamics: Systems thinking and modeling for a complex world*. McGraw Hill.

Stevens, R., Johri, A., & O'Connor, K. (2014). Professional engineering work. In A. Johri & B. M. Olds (Eds.), *Cambridge Handbook of Engineering Education Research* (pp. 119–137). Cambridge University Press.

Turner, H. M., III, & Bernard, R. M. (2006). Calculating and synthesizing effect sizes. *Contemporary Issues in Communication Science and Disorders*, *33*(Spring), 42–55. https://doi.org/10.1044/cicsd_33_S_42

Appendix A.
Case study curricular plan summary: Wind farms: Jepírachi, Colombia

Week	Prior to class	In class
1	• Case study introductory reading of 3–4 pages single spaced with technical and contextual details that synthesizes information from many different resources • Online quiz	• Spanish vocabulary search and use using case study • Online quiz game • Watch news report about the project which shows the ecological landscape, native people's voices, engineering outcomes, and community impacts • Analyze the news report through answering related questions and small group discussions • Critically analyze the interrelations between the Colombian government and Wayúu people, the visibility of the Wayúu people and the economic and political benefits of the project, and the competing interests between traditional ways of life and modern technologies and cultures
2	• Read "10 steps in building a windfarm." Define the process of building a windfarm (technical and contextual considerations). Identify the most complex step in the process and explain why it is the most complex • Read cultural information about the Wayúu people and consider their potential response to the idea of installing an antenna; post responses to the online discussion board and respond to at least one classmate's post with 40+ words	• Introductory activity about cultural change and new technologies • Critical analysis of engineering technical goals which include maximizing production, minimizing costs, and following legal guidelines related to the country and the environment • Technical considerations of a wind farm for specific locations: workings of a wind turbines or wind generators, related civil engineering projects, related electrical engineering projects, adequate conditions for optimal function
3	• Read Colombian government website with details about the project • Online quiz	• Negotiations with the Wayúu people: Introductory ideas to consider • Structured role play of negotiations in small groups, considering economic, social, cultural, and environmental considerations
Final Assignment	• Final analysis of the case study and role play meta-analysis	

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Appendix B.
Sample final essay for the Jepírachi, Colombia case study

Sample essay 3:
Renewable energy on the native lands of the Jepírachi people

You need to write an essay of at least 1200 words (max. 1400) that includes the following information:

Part 1. (At least 600 words)

1. List and explain civil and electrical works required to assemble a wind turbine.
2. Explain the wind conditions for the optimal operation of a wind farm.
3. Compare a wind farm and a solar farm in terms of initial investment, maintenance, efficiency, the power generated, and risks.
4. Write about traditions that the indigenous people commonly have regarding land, water, wind, and their ideas related to the sun and the moon.

Part 2. Role playing (At least 600 words)

A minority group in a country lives in a remote area of the city. This community lives comfortably with basic services and is self-sufficient in that with the vegetables and meat that they produce, they can fully support themselves. The government has decided to build a highway that crosses the territory where this minority community lives. The road serves to connect two large cities, reducing travel time. It is a project that benefits the country and includes a modification of the terrain and landscape where the ancestors of that community have lived for hundreds of years. Some families may have to be relocated. The land is considered sacred in the community, and they have never wanted other people to live or enter their territory.

Questions:

1. You are the leader of the minority community; what do you think should be done?
2. You are the secretary of national transport; what arguments do you have to press for the highway to be built? If you get the community to accept, you will receive an increase in your job position and salary.
3. Finally, will the highway be built or not?

Appendix C.
List of questions that students respond to as part of the Village of Abeesee scenario assessment, taken from Grohs et al. (2018).

1. Given what you know from the scenario, please write a statement describing your perception of the problems and/or issues facing Abeesee.
2. What additional information do you need before you could begin to develop a response in Abeesee? Consider both detail and context of the problems/issues you identified.
3. What groups or stakeholders would you involve in planning a response to the problems/issues in Abeesee?
4. Please briefly describe the process you would use to plan a response to the problems/issues in Abeesee.
5. What would you expect a successful plan to accomplish?
6. Given what you know and a budget of $50,000, develop a plan that would address the Abeesee situation maximizing the impact of your $50,000. Use a numbered, step-by-step guide, recipe-style to explain.
7. What challenges do you see to implementing your plan? What are the limitations of your approach?
8. Please describe any unintended consequences that you think might result from this plan.

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