



## Raising Students' Cultural Awareness through Design Scenarios

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## Introduction

For many reasons, stakeholders from academia and industry are urging universities to produce globally competent engineers. For example, the ABET EC 2000 outcomes require that engineering graduates “understand the impact of engineering solutions in a global, economic, environmental, and societal context” (p. 3).<sup>1</sup> The view that engineers must be prepared to competently navigate a variety of cultural contexts is further expressed in the National Academy of Engineering’s well-known *The Engineer of 2020* and *Educating the Engineer of 2020*.<sup>2-3</sup> Both reports argue that, among many other characteristics, engineers need to develop an awareness of sociocultural issues that have been and will continue impacting engineering practice. As put by Katehi, “U.S. engineers must become global engineers. They will have to know how to replenish their knowledge by self-motivated, self-initiated learning. They will have to be aware of socioeconomic changes and appreciate the impact of these changes on the social and economic landscape in the United States and elsewhere. The engineer of 2020 and beyond will need skills to be globally competitive over the length of her or his career” (pp. 152-153).<sup>3</sup>

But while this need may be well-recognized,<sup>4-5</sup> the motivations for producing globally competent engineers vary across a number of stakeholders. For example, the Newport Declaration includes a very diverse set of rationales for global engineering education.<sup>6-7</sup> The declaration characterizes how globalization dynamics and discourses affect traditional views of engineering, with regard to how it is taught and practiced. While recognizing the need to prepare engineers to support national economic prowess in a competitive world characterized by rapid social and technical changes, it also stresses the somewhat contrasting ideas of promoting global outreach, community, and collaboration.<sup>6-7</sup> In the midst of seemingly paradoxical rationales, ranging from concerns of competition from industry to those voicing concerns of sustainable community development and global citizenship, multiple stakeholders find consensus on this sentiment – the time for globally competent engineers is nigh.

## Theoretical Framework: Global Competency

But what do we mean by global competency? We employ the definition given by Downey et al., which describes a globally competent engineer as one who “work[s] effectively with people who define problems differently than they do” (p. 110).<sup>8</sup> Moreover, we understand navigating across cultures to be a salient characteristic of working effectively with those “who define problems differently.” We understand *culture* to be “dominant images” (p. 5),<sup>9</sup> a framework also proposed by Downey and Lucena.<sup>10</sup> Lucena nicely articulates this understanding of culture: “[I]ndividuals living and working in a particular spatial and temporal location are challenged by dominant images. Dominant images create expectations about how individuals in that location are supposed to act or behave. In this ... concept of culture, the image remains the same over a period of time, while individual or group reactions to the image’s challenge might differ” (p. 5).<sup>9</sup>

We might illustrate this framework by considering a well-recognized “engineering problem” such as providing access to clean water (as mentioned in the NAE Grand Challenges).<sup>11</sup> If, for example, a rural community in West Africa is faced with the challenge of *not* having access to

pure water, and an engineering student team is addressing such a challenge, the members of the West African community and members of the engineering team are likely to have different response to the problem “limited access to pure water,” Including different cultural images associated with water in general, and clean water, in particular. If the engineering team were to only consider a purely technical solution to accessing pure water, they might be blind to the fact that the community members could have relevant forms of local knowledge and responses with regard to this same problem which are in turn inflected by a variety of cultural images. Thus, we recognize *culture* to refer to how individuals and groups are challenged by and respond to certain dominant images. And when we use the term *cultural awareness*, we refer to one’s awareness that different cultures are defined by different assemblages of dominant images, and certain individuals may respond differently when encountering various cultural images.

We presume that such *awareness* is a necessary prerequisite for developing global competence. As demonstrated by a longer history of engineering and development, partnerships between engineers and global communities can be considerably complex, including due to the general cultural differences between the partnering groups. When working with partners in developing countries, cultural differences increase the possibility of failure, as evidenced by many examples of community service projects that were not accomplished because of a lack of sensitivity toward cultural differences (e.g., see EWB Canada Failure Reports<sup>12</sup>). Moreover, the communities that engineers intend to serve may actually be disempowered intentionally or unintentionally by otherwise well-meaning engineers.<sup>13</sup> Hence, it becomes vital to raise students’ cultural awareness from the beginning of their community development experience, especially so they can consider and address social and cultural considerations in their decisions during all stages of the design project.

### **Educational Approaches to Producing Culturally Aware Engineers**

Engineering schools have developed a variety of educational methods aimed at educating student to be culturally aware engineers.<sup>14-16</sup> Among these methods, global service-learning programs have increasingly entered engineering curricula. In many of these programs, students respond to a problem found in an international context during the course of one or more semesters. Additionally, they might travel abroad to deliver designed product.<sup>16</sup> One of the oldest global service programs for engineers is the Global Perspectives Program (GPP) at Worcester Polytechnic Institute (WPI), which is designed to engage students in open-ended ambiguous problems situated outside of their major disciplines while exposing them to cultural, social, and intellectual diversity.<sup>17</sup> Moreover, Michigan Technological University has developed several global service programs at both the undergraduate and graduate levels that combine field trip, technical courses, and project-based service learning so that students can learn about concepts of sustainability and social justice.<sup>18-19</sup> Many similar programs exist at other universities, indicating that it is common to send students and staff to another country as part of their design experience, often to conduct a preliminary assessment of needs or deliver/install a completed project.<sup>20-21</sup>

Such international travel often provides significant learning with regard to navigating across cultures for students that participate. Unfortunately, such travel experiences are not often accessible to most students due to a number of factors (as reviewed by Parkinson).<sup>16</sup> Moreover, Jesiek, Shen, and Haller found that students with lower levels of cross-cultural competence, as

measured by the Miville-Guzman Universality-Diversity Scale-Short form (MGUDS-S), are less likely to participate in such experiences in the first place.<sup>22</sup> Such observations suggest the need for “stepping stone” interventions to foster global competency in a broader range of engineering students, and particularly those who are not as likely to self-select into global experiences.<sup>22-23</sup>

How, then, might students learn to navigate their engineering career with global competence without experiencing a different culture firsthand? Additionally, how can we prepare students to navigate across cultures before immersing them in a different context? A growing number of resources and documented models make such learning possible. For example, content from Downey et al.’s *Engineering Cultures* curriculum, along with many other resources, are available on the GlobalHUB website (globalhub.org).<sup>8</sup> Other examples of such resources include textbooks for students<sup>13</sup>, documented case studies of failed projects (e.g., EWB Canada Failure Reports<sup>12</sup>), as well as initiatives to train faculty to develop high quality service-learning experiences (e.g., E-FELTS, EPICS Workshop<sup>24-25</sup>). Additionally, since 2012 Jesiek et al.<sup>26</sup> have led organization of an annual Global Engineering Design Symposium (GEDS) at Purdue University to help prepare students for work on global service-learning projects.

## **Research Context and Questions**

Recently, the EPICS program at Purdue University has given students expanded opportunities to partner with organizations and universities in developing communities. Most if not all of the students’ design work occurs domestically, in contrast to the aforementioned programs that have clear travel components. Yet even without this travel component, one study suggests that EPICS is an effective transitional, or “stepping stone”, experience to developing global competency.<sup>23</sup> As a strategy for further enhancing such competency, we developed three hour learning module for students enrolled in a multiplicity of EPICS project teams. Among many different cross-cultural strategies, we decided to use scenarios adapted from real cases and situations which illustrate how culture can deeply effect how engineering problems are defined and solved. This paper reports results on the effectiveness of this teaching strategy by addressing the following research questions:

1. At the end of the skill session, were students better able to identify cultural aspects as relevant factors when solving a given design task?
2. How did students reflect upon the re-evaluation of their proposed solutions as compared to their initial approach?

## **Methods**

### *Research Context and Intervention*

Data for this paper were collected from a skill session titled “Partnering with Developing Countries.” This three hour learning module was open to any student enrolled in the EPICS program at Purdue University. The skill session was developed by the first author, in collaboration with the second author and three EPICS teaching assistants, in part to fulfill a requirement of a graduate course in the School of Engineering Education at Purdue University. All work was completed under the guidance of Drs. Zoltowski, Abraham, and Oakes, who were

teaching the course. The objective of the skill session was to teach students about the importance of factoring in cultural aspects of their project partners in the design process. In order to achieve such an objective we used a variety of tools and strategies. During the skill session students were shown two scenarios that described community development projects that were deeply influenced by cultural differences. The first scenario was originally posted on Engineers Without Borders Canada's Admitting Failure web site.<sup>27</sup> It describes a small business project in Benin organized by a Peace Corps Volunteer that failed because he assumed the local community members would have behaved as Westerners in the same situation. After reading the story students were asked to reflect, first alone and then in pairs, about the reasons that caused the failure of the project. Then, the first author facilitated an open class discussion that aimed to point out the dangers of not considering cultural assumptions in the design process.

The second scenario was adapted from a personal experience in a developing country, as related by Riall Nolan, Professor of Anthropology at Purdue University. Students were initially given the design problem and asked to choose among four solutions, among which the technically correct one was culturally unacceptable. However, they were not given any information about the culture of the local community. Then, students were given critical information about the local culture and asked to choose again so that their solution would embrace the local cultural norms. Students also interacted with three engineering teaching assistants, all of whom had engaged in rich, cross-cultural experiences. These teaching assistants told stories about their cross-cultural experiences and what they learned from those experiences. Finally, the second author led a presentation on strategies about gathering information from project partners and stakeholders.

### *Subject Group*

Participants were engineering and non-engineering undergraduate and graduate students enrolled in a variety of domestic and international EPICS project. Since registration to the skill session was open to any EPICS student, there was no prior selection of the subject group. A total of 40 students registered and, of the 32 students who attended, 28 turned in a study instrument. One student did not complete the entire form, and another declared to have already attended a similar skills session, hence they were excluded from further analysis. Of the 26 students whose answers were analyzed, 15 indicated that they had lived two or more months in a foreign country, four were international students, 13 were female, and 14 affirmed being able to attend college level courses in a second/non-native language. Students provided five answers for both the pre and post questions, thus a total of 260 answers were coded. Among those, 6 were left blank and as a consequence findings in the next section refer to a total of 254 valid answers.

### *Study Instrument*

As documented by Jesiek and Woo, a small but growing body of work has involved use of scenario-based assessment instruments to evaluate specific areas of competence among engineering student populations, with particular emphasis on design skills and abilities.<sup>28</sup> Particularly relevant to the present investigation are studies where respondents are asked to generate a list of specific criteria or factors that should be taken into account when addressing a realistic engineering design problem, e.g., the well-known "Midwest Floods Design Task."<sup>29</sup> Scenario-based questions have also been used to study aspects of global competency, including

understandings of how national differences are important in engineering work,<sup>8</sup> and perceptions of desirable attributes for global engineers.<sup>30</sup> Scenario-based approaches to research and assessment are appealing for many reasons, including their grounding in realistic contexts of practice, and ability to more directly probe student abilities and perceptions rather than relying on indirect evidence, e.g., via self-assessments. Such questions are also readily used as scaffolds for teaching and learning, including in tandem with case-based instructional approaches.

In order to answer our first research question, participating students were given the design task shown in Figure 1 at the beginning and end of the session. The task was inspired by the prior work of Pandian, who explains how playground devices such as a seesaw, merry-go-round, and swing can be used as human-powered energy conversion systems.<sup>31</sup> While he briefly notes that “[e]thical questions may be raised on the *use* of children for power generation,” the dominant focus of his article is a detailed discussion of the technical aspects of such a solution, suggesting it would be ideal for communities in developing countries. However, the author did not take into account any of the sociocultural aspects of the project. Inspired by previous work by Jesiek et al., the answer box included numbers 1-5 to encourage students to provide five distinct answers.<sup>30</sup> To address the second research question, students were also asked to indicate whether their answers to the design task changed and to explain the reasons for this change (or lack thereof).

In developing countries energy production is one of the most critical problems. Resources or technologies to exploit resources are often not available. Thus, human power conversion systems are often used to power small appliances.

Imagine that you and your team are assigned to a design project in partnership with a Non-governmental Organization (NGO) of a developing country. Your partner needs a low-cost power system that can generate enough energy for the lights of a children’s playground. One of the members of your team suggests using merry-go-round, seesaw, and swing to produce energy that can be converted to electricity for the lights. You all like the idea and decide to design such a system.

In your opinion, what are the top five things you need to consider in order to successfully accomplish this design task?

**Figure 1. Design task inspired by prior work of Jesiek et al. and Panadian<sup>30-31</sup>**

### *Data Analysis*

The final rubric for classifying students’ responses to the design task is illustrated in Table 1, which also reports examples directly taken from student responses. Answers that considered purely the physics of the devices, such as power and materials, fell into the *technical* category. If the language did not include stakeholders or looked for quantity (as related to non-technical factors), the answers were labeled as *constraints*. When participants explicitly talked about stakeholders; by either just mentioning them (e.g. students simply wrote “stakeholders”), or specifically articulating them as related to constraints (“safety of children” vs. “safety of device”), the answers were coded as *stakeholders*. Finally, if students explicitly talked about culture, questioned assumptions, or recognized that the stakeholders might be different than the designers; answers were coded as *culture of stakeholders*. By following such a coding scheme, if students simply wrote the word “materials”, the answer would have been coded as ‘technical’; if they wrote “availability of materials”, coded as ‘constraints’; and if they wrote “are materials available in the country?”, the answer would fall in the “culture of stakeholders” category.

| <b>Category</b>              | <b>Definition</b>  | <b>Example</b>   |
|------------------------------|--|--|
| Technical (T)                | considers purely the physics and/or material properties of the system and/or components; does not seem to recognize that materials might be different than the U.S. in the setting of the scenario.  | “Materials for making the merry go-round,...”<br>“Is there any way to store the power?”<br>“where/how the power will be converted”<br>“if the devices will supply enough energy to keep the lights running”<br>“How much power is generated with this system”  |
| Constraints (Co)             | language regards people that interact with the devices only in terms of how they will interact with and/or affect the system; e.g., people are considered as a mechanism to operate the system or as an entity to be harmed by the system; the language is centered on the functionality of the system rather than the people; the item indicates a concern for quantity of people interacting with the system rather than the concerns of the people themselves. If an item is too vague to determine whether it belongs to Co or others, assume this category. | “Safety - no loose wires, mounted properly”<br>“How many children use this playground?”<br>“Economic efficiency low budget project”<br>“Cost” “number of children”<br>“maintenance”<br>“sustainability of the item”<br>“resources available”   |
| Stakeholders (S)             | explicitly mentions and/or describes stakeholders or people who interact with the system; items seems more concerned with the people themselves rather than how they will interact with the system.  | “stakeholders”; “Safety of the wires/electricity near children (children should be unable to be harmed)”<br>“who is going to actually build the system”; “who would be able to maintain the equipment”   |
| Culture of stakeholders (Cu) | explicitly mentions culture, recognized differences in the student’s culture and the culture of the scenario – even if they did not know what those differences were; questions assumptions about the location or the people that are presented in the scenario; recognizes that their assumptions may not be correct in the host culture in the scenario.   | “Would the people in the developing country know what these "toys" are?”<br>“Whether the community wants this project/what their expectations are.”<br>“whether the idea is acceptable to the community member”; “are the materials easily procurable in that location”<br>“obtain an advisor translator”<br>“Project is simple enough for locals to fix/repair project should be able to be fixed with local resources” |
| Unknown (UK)                 | Answers are too general to clearly fall in any of the above categories   | “communication”<br>“ambiguity”   |

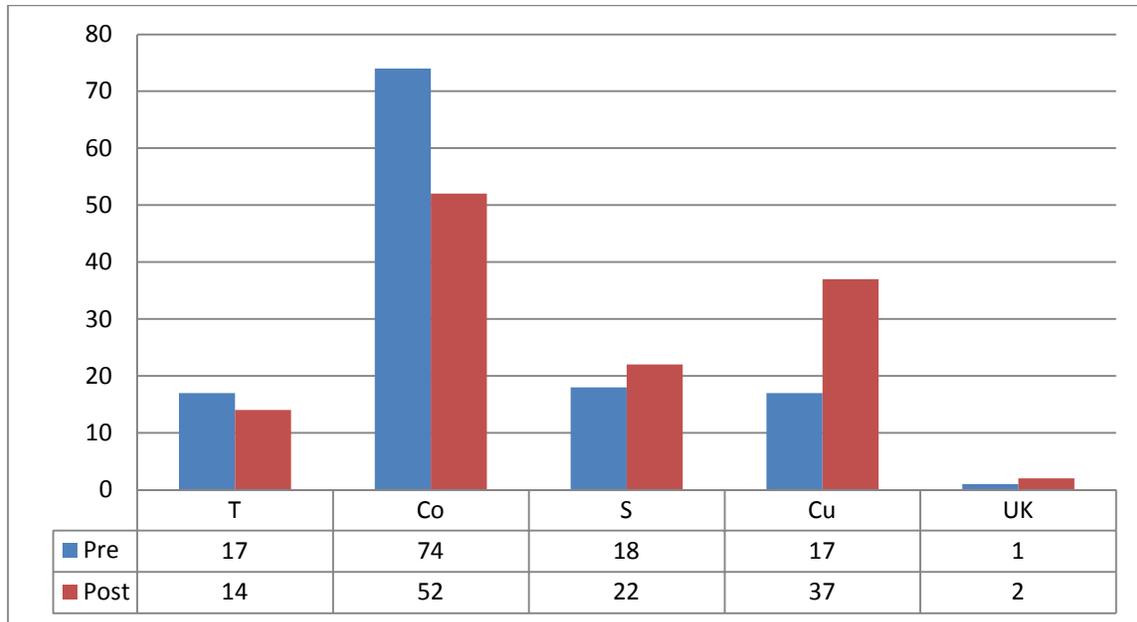
**Table 1. Design task coding categories, definitions, and examples**

## Findings

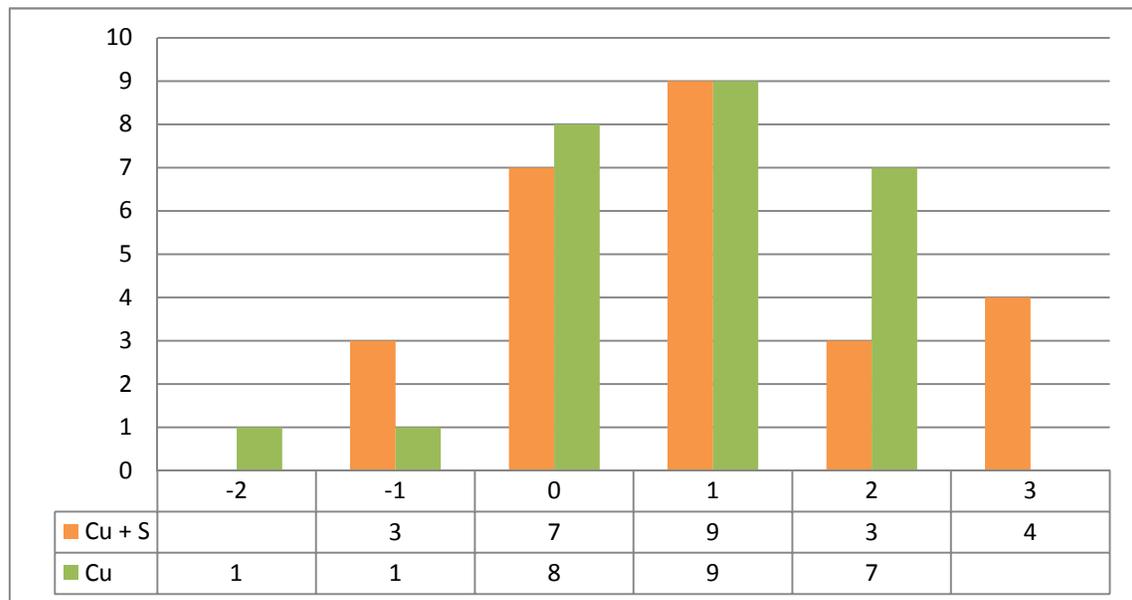
In order to answer the first research question, we looked at pre/post-session changes in answers by counting the number of instances for each coding category. Table 2 reports the pre/post-session change in the total number of instances for each category. In general, the results show a clear drop in answers belonging to the *technical* (T) and *constraints* (Co) categories, and a consequent increase in the number of answers in *stakeholder* (S) and *culture of stakeholder* (Cu) responses. The number of instances in the Cu category more than doubled. We also looked at the change in the number of Cu and S together, and Cu alone instances, for each student. As shown in Table 3, 16 students added at least one answer belonging to the S or Cu categories in their post-session responses, with four students presenting three additional instances falling in the Cu and S categories. Similarly, 16 students included at least one Cu instance more than in their pre answers, with 7 students adding two Cu instances. Wilcoxon signed-rank tests were conducted on the data, which revealed significant gains in responses coded as Cu ( $p < 0.01$ ) as well as the sum of responses coded Cu or S ( $p < 0.01$ ).

In order to address the second research question, we looked at the open-ended question in which students were asked to reflect about their change between their pre and post-session answers. From Table 3, we selected the four students presenting the maximum change between the pre and post answers regarding Cu and S categories, and the three students that presented a decrease. As reported in table 4, Mary, Jennifer, John, and Michael, who all presented an increase in S or Cu answers, explicitly stated that their answers changed in order to take into account cultural differences. Both Jennifer and Michael were more sensitive to non-technical aspects of the project that were not known or evident at the beginning. Additionally, Michael raised concerns about communication methods with the local population (“advisor/translator”), while Mary and Jennifer showed a broader understanding of stakeholders involved in the project by identifying other individuals who were not mentioned in the design task (i.e., children and NGO): “others who might not be users” (Mary) and “the people there” (Jennifer).

Conversely, Juan, Elizabeth, and David were the only students who responded with a diminished number of design considerations focused on stakeholders and the culture of stakeholders (S+Cu categories). Juan, who is an international student, stated that he changed his answers, and in his explanation, similar to Michael, expressed concerns about communication methods with the stakeholders and partner. However, in his actual answer to the prompt he never mentions communications issues. Nonetheless, Juan dedicated the large part of his answers to stakeholders and culture of stakeholders in the pre-test. Finally Elizabeth and David stated they did not change their answers, except for wording (Elizabeth) and order of importance (David).



**Table 2. Total number of design task answers belonging to each coding category (On the x-axis T = technical, Co = constraints, S = stakeholders, Cu = Culture of stakeholders, UK = unknown.)**



**Table 3. Number of students who increased or decreased the number of answers belonging to the Cu or S category, and the Cu category alone. On the x-axis negative numbers indicate a decrease, while positive numbers indicate an increase.**

| Fictional names and pre/post change in responses coded Cu and S (pre/post) | Students' perception of their change   |
|--|--|
| Mary<br>+3 (1/4)   | "They are different. I now consider the people, the local culture, the regulations. So it's not just our project and the users, but also others who might not be users but have powerful voices that could effect the success of our project"          |
| Jennifer<br>+3 (0/3)   | "My answers are different because at first I was thinking in a logical way about the things I already knew about. The second time I was more aware of cultural things that I did not know about that would actually genuinely affect the people there" |
| John<br>+3 (1/4)   | "They are more about the culture of the country and how it will affect the design process"   |
| Michael<br>+3 (1/4)  | "A few answers changed to take into account cultural differences that might not be evident at first. Having an advisor/translator to uncovering unknown elements needed for the design"  |
| Juan<br>-1 (4/3)   | "yes there was a difference. Initially, I was more concerned about implementation issues. Now, I had put in more concern our communication with the stakeholders and partner"  |
| Elizabeth<br>-1 (1/0)  | "My answers were the same. I changed a few wordings but the basic questions were the same"   |
| David<br>-1 (2/1)  | "they are the same but in different order of importance"   |

**Table 4. Students perception of their change in answering the pre-post design task (In the left column, fictional names and change in the number of answers belonging to the 'stakeholders' and 'culture of stakeholders' categories are listed. The first number in parentheses refers to the number of Cu or S answers in students' pre-event form, while the second number refers to their post-event response. On the right, their original answers to the open-ended question are reported. No changes were made to the wording or grammar of their answers.)**

### **Conclusion and discussion**

As shown in Tables 3 and 4, there is considerable evidence to indicate that most of the students were more concerned about the stakeholders and the culture of stakeholders in approaching the design task at the end of the skill session. The number of responses falling within these categories increased noticeably, and the number of responses that referred to the culture of stakeholders more than doubled. Additionally, most of the students added at least one response

regarding stakeholder and cultural factors, including detailed formulations such as “understand stakeholders: daily life, equipment, tasks, culture.” Others stressed how important it is to “make connection with the area to gain information,” and to “obtain an advisor/translator” so they could “communicate the project information.” Finally, students were more likely to question the appropriateness of the project and whether it met the needs of the local communities, such as by asking questions like “are those the best/appropriate pieces of playground equipment for that country?”, “Does the culture even like those playground structures?”, “is there really a need?”

The open-ended answers also suggest that students themselves perceived an actual change in their way of approaching the design task. When students showed an increase in the number of S and Cu categories, they explained this saying that they began considering “the people, the local culture, the regulation” and by expressing the importance of learning more about the local community. As one respondent explained, “The second time I was more aware of cultural things that I did not know about that would actually genuinely affect the people there.” One student also explicitly talked about “the danger and easy trap of assumptions” and noticed that his “original response was based a lot on assumptions.” However, a few students did not present any change in the number of answers regarding stakeholders and cultural factors, and three students presented a decrease. Of those students, one student (Juan) presented very culturally sensitive answers, however the actual number of such answers decreased. Being that Juan a not native English speaker, part of the reason might be explained by his inability to clearly express what he had in mind. Moreover, the other students’ open-ended answers reflected their lack of change. As a consequence, the skill session might not have been so effective for the four students, whose responses presented a decrease in the number of cultural and stakeholder responses.

In sum, both students’ responses to the design task and their reflections suggest that the use of instructional cases and assessment scenarios that merge technical and sociocultural factors can be an effective strategy to engender cultural awareness in a large number of engineering students. However, this method needs to be further refined and improved, including to better establish its effectiveness and validity, and to allow better scalability to reach a larger number of students.

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