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Intercultural and linguistic competences for engineering ESP classes: A didactic framework proposal through problem-based learning

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Global competencies are crucial for societies to progress in a changing world. Beyond the specific language skills needed to be integrated into an international workforce, individuals should also develop the capacity to analyze and understand intercultural issues in their fields. In light of this, our paper firstly aims to pilot a problem-based learning (PBL) proposal around a cultural critical incident for design engineers to develop intercultural and linguistic competences in an ESP engineering course. A secondary objective investigates how the project raises students' awareness about cultural factors in product design. The results point to PBL as a method which enables instructors to integrate intercultural and linguistic skills in engineering programs, where students' awareness of cultural factors can be increased through problem-solving teamwork on critical incidents.

KEYWORDS
critical incidents, engineering, intercultural competence, problem-based learning

Las competencias globales son claves para que las sociedades avancen en un mundo cambiante. Más allá de las capacidades lingüísticas necesarias para integrarse en un mercado laboral internacional, también debe

desarrollarse la habilidad de analizar y comprender problemas interculturales que pudieran surgir entre diferentes áreas. Nuestro trabajo tiene como objetivo principal diseñar una propuesta de aprendizaje basado en problemas (ABP) en torno a un incidente cultural crítico para capacitar a estudiantes de ingeniería en diseño industrial en la adquisición de competencias interculturales y lingüísticas. Un objetivo secundario investiga cómo el proyecto aumenta la percepción de los estudiantes sobre los factores culturales en el diseño de productos. Los resultados apuntan al ABP como un método que permite integrar habilidades interculturales y lingüísticas en programas de ingeniería, donde la asimilación de dichos factores por parte de los estudiantes puede mejorar mediante el trabajo en equipo en torno a incidentes críticos.

PALABRAS CLAVE
la competencia intercultural, el aprendizaje basado en problemas, ingeniería, incidencias críticas

1 | INTRODUCTION

The coming years will see the demand for design engineers ready and able to work in a diverse and international environments, for professionals with specific and global skills. Such skills include a determined level of foreign language proficiency, in this case English, to finish undergraduate engineering programs, which responds to a concrete linguistic requirement. On the other hand, students are expected to gain more abstract skills, like a certain level of intercultural competence (IC), required in cross-curricular competencies for undergraduate engineering programs in the European Union as established by the European Higher Education Area (EHEA) (Bridgestock, 2009). Intercultural competence includes cognitive, affective and behavioral dimensions (Bennett, 2013; Deardorff & Ararasatnam-Smith, 2017) such as cultural difference acknowledgment, or awareness, (cognitive), tolerance for diversity (affective), and learning both culturally appropriate verbal and nonverbal language (behavioral, given that speech and nonverbal communication, such as gestures, are corporal actions which communicate meaning (American Psychological Association, 2021). The cultural awareness that students need to be successful in this sense are based on values like tolerance and respect for others, so-called soft-skills, which are vital to progressive societies. These cultural soft skills are a natural inclusion in language classes due to the close relationship between language and culture (Citron, 1995). Engineers with language skills who can operate with nuanced understanding of cultural differences can better determine the true functionality of their proposals for a given group of people in different parts of the world (Alexander et al., 2014).

Yet, because of the socio-psychological nature of these soft-skills, didactic frameworks for teaching intercultural competence in language class are much debated. One way to examine these diverse facets has been to approach them from the perspective of cultural critical incidents. Critical incidents have long been used for intercultural competence training to present and analyze real situations of conflict that occur over friction caused by cultural differences, as an exercise in understanding how such conflicts arise.

Based on a prior needs analysis, this paper will offer a novel didactic proposal for teaching engineering students language as well as intercultural competence in English for engineering courses, specifically through problem-based learning (PBL) based on critical incidents from the field of cultural design engineering. Problem-based learning promotes critical thinking and problem-solving skills, as well as linguistic development through staged group work. Critical incidents, though frequently used in cross-cultural training and language courses, have not been adapted to engineering in a pedagogical context. We will thus add a new dimension to the current literature on how to teach intercultural competence, an obligatory cross-curricular competence in the language classes which form part of the current engineering curriculum in the EU. The paper structure will go as follows. We will begin by reviewing the needs analysis that led us to this project, and then continue to an exploration of theoretical considerations in intercultural competence, including critical incidents and active teaching methodologies. Then we will explain the study undertaken in terms of its objectives, population, and methodology. Finally, we will look at the results of this project and its impact on student opinions about culture in design and discuss their importance, finishing with the conclusions reached.

2 | BACKGROUND

2.1 | Needs analysis

Needs analysis are especially helpful for English for Specific Purposes (ESP) students given the greater demand of communicative language tasks of many professional environments (Todea & Demarcsek, 2017; Xia, 2020) as well as the specific vision into the sort of English that their future field requires. In the case at hand, engineering students' needs can be examined in two contingent areas: their English language needs, and their intercultural competence needs. The 4-year bachelor's degree in Industrial Design and Product Development in which the students under study here are enrolled aims to produce graduates capable of improving existing products or managing the entire life of a new product, from its inception as an idea through the product's production, launch, and environmental impact at the end of its useful life. Successful graduates' designs should ultimately better the products' chances for success in the market, paying attention in particular to function, cost and potential client profiles. This last aspect is of particular importance to our purposes here, since the future markets students design for will inevitably include international clientele and teams. For that reason, in terms of the academic context, the degree program pushes students to reach a high intermediate level of English (B2 on the CEFR scale) that develops all four language skills, with special focus on productive skills (speaking and writing). This is done through language subjects in the degree like *Technical English*, an obligatory course, and *Multimodal Communication in English*, an optional course and the one in which the students under study here were enrolled.

The *Multimodal Communication in English* course is a class conducted primarily in English. The class employs a communicative approach to language teaching that places emphasis on students' active participation and oral skill work in the context of engineering. The stated course focus in its syllabus is on developing communicative skills for using English and on semiotics in English as it applies to design engineering, including (by modules): interfaces, products, advertising, packaging, logo design, and branding (Rico García, 2019, p. 2). One unit is devoted to "Semiotics and Culture in Design" which is where this project takes place. The unit took place over a period of 4 weeks, with a total of 16 hours of class time and approximately 6 hours of work outside class dedicated to the PBL project discussed here. As mentioned in the introduction, the Industrial Degree in Design and Development includes specific, cross-curricular objectives for cultural competence in the program, mandated at the national level by the European Higher Education Area (EHEA), which are:

- the cross-curricular competence: diversity and intercultural competence; and
- the content objective described as the development of cross-curricular skills including intercultural competence, respecting diversity and interpersonal communication.

In terms of voices from professionals in the field, scholars agree that engineering is increasingly globalized in terms of teams, projects and mobility, requiring up and coming engineers to continually "look outward" (Kamp, 2020). This points toward a nascent demand for both language and intercultural skills. In terms of the latter, professionals and scholars note that cultural skills in particular are sorely lacking both in graduating engineers and in engineering study programs (Handford et al., 2019; Mahalik et al., 2008; Riemer, 2007). As Handford et al. (2019, p. 1) put it:

> intercultural communication has not received the attention it deserves, given the multidisciplinary, diverse, global nature of the engineering profession. Furthermore, when intercultural concerns are discussed, the predominant approach is essentialist, meaning that culture is regarded as given (rather than constructed), framed in terms of differences between nations and potentially offering a causal explanation for individual behavior. This approach has been criticized for reinforcing stereotypical thinking and offering simplistic answers to complex problems.

In an in-class needs analysis, we noted that this overly simplistic view of culture is present in the class under study here (and it has been observed with previous groups in the same course): that students are traditionally comfortable with static concepts of culture which do not engage with authentic and complex contexts of interaction, or authentic language for that interaction. In class discussions for the group under study, when asked at the beginning of the semester if and how culture should be a part of product design, students' answers primarily expressed opinions that assume most of the international markets of their future careers would be ultimately similar simply because they share technological developments, with blanket statements that ignore important cultural nuance, like "Everyone is doing the same thing, really … Internet, doing Tik-Tok, watching Youtube. It's a very connected world" (Rico García, 2018). For this reason the pilot project was begun: to better develop students' intercultural competence in a way that promotes deeper thinking about culture. This more profound consideration of the role of culture is focused on through critical incidents, which reveal underlying cultural expectations, and honed through problem-based learning, which allows for a progressive, group approach to learning that fosters critical thinking and productive language practice.

2.2 | Intercultural competence revisited in a global age

Intercultural competence at its most basic level speaks to the fact that the world is ever smaller and more complex, and so our need to cooperate across and despite our cultural differences is increasingly important. In this paper, we define intercultural competence through Borghetti (2017, p. 1), where IC is conceived "as an integral whole of cognitive, affective and behavioral factors that influence the understanding of, and interaction with, diversity in a broad sense, and which can be developed through education and/or experience." From a language learning perspective, intercultural competence is a complex phenomenon in which Borghetti (2017, p. 1) includes "how individuals socially position themselves in interactions (e.g., according to their nationality, genre, age, social status, etc.), to their awareness of such positioning, and to their willingness and ability to recognize and negotiate the others' multiple identities as much as their own." Intercultural competence then has both concrete and abstract roles in language learning. Concretely, as Citron (1995) notes in a seminal paper on IC and language teaching, culture is embedded in language and language reflects the "culturally-bound" nature of our communications, such as the untranslatability of some words, where some terms exist singularly in a given culture and may not exist in another.

On the other hand, and more central to the study here, intercultural competence has a more abstract role in learning languages, where cognitive awareness of cultural identity as multifaceted and individual is key to being able to both recognize the cultural factor in design, as well as negotiate intercultural encounters with others as one designs in increasingly international environments. In the case at hand, these encounters occur at students' future workplaces, so that they must learn to rein in the cultural assumptions (both about themselves and others) implicit in how and what

they communicate in English. Many courses assume that IC skills are acquired through working cultural sidenotes in course textbooks, which as Handford et al. (2019) remark, represent a dangerously static view of culture itself.

2.3 | Critical incidents for intercultural competence

A hallmark for intercultural competence is firstly recognizing cultural difference, or becoming aware of this difference, and then being able to integrate into this difference (Bennett, 2013) on a road from ethnocentricity, seeing one's culture as central, toward greater ethnorelativity, seeing one's culture as one of many on equal footing. Intercultural critical incidents are examples of interaction gone awry, where cultural difference has created tension and conflict. By analyzing critical incidents where cultural difference is present, one may work her or his ability to see situations from the viewpoint of different cultures. In terms of past applications of critical incidents in higher education, Apedaile and Schil (2008) developed critical incidents as a base for a handbook for intercultural training in higher education for a general university audience, with didactic material for classroom use. Arthur (2001) examines university students' study abroad experiences in Vietnam through critical incidents and makes suggestions for pre-departure training for more effective study abroad programs. Hiller (2009) looks at intercultural conflicts between German and Polish students studying together at a cross-border university and notes the need for more specific methodological applications to be made to the critical incidents technique, specifically because of problems with the extent to which individual critical cases can be generalized. To treat this, Hiller (2009, p. 1) offers a new methodology called the Extended Critical Incident Approach (ECIA) which is based on the definition of critical incidents as an event where "culture will become relevant as a factor if the assumptions of normality and expectations of plausibility of the interacting individuals collide on culturally-immanent knowledge of the spectrum of differences," which we will take into account in this study.

Although critical incident methodologies have been applied to the higher education classroom (Snow, 2015), and in language education (Nugent, 2015; Tran et al., 2017), no application has been made within the field of English for design engineering. This would be a much different application in theory because of how intercultural competence engages in the field with larger issues specific to engineering mentioned earlier: globalization and internationalized markets, teams and projects. Projects undertaken in the field for example, may involve diverse geographical areas or products. One product may satisfy or offend a potential customer because of different cultural characteristics of the customer in consideration in one of these areas, but not in another (Van Bossuyt, 2009). Van Bossuyt notes that, for example, individuals may react differently to colors or smells for cultural reasons, and that this is important in considering, for example, how to design a lavatory air freshener or warning signs for an airplane carrying international clientele. For this reason, critical incidents may be useful for teaching intercultural competence to design engineering students studying English when they take into account this impact, putting intercultural competence in focus in both the immediate and more global picture.

2.4 | Active methodologies: problem-based learning

Engineering students are often said to lack connection to real-world applications in the classroom (National Academy of Engineering, 2012). Problem-based learning, the approach chosen for this study, puts real-world application of a theoretical issue into focus through a concrete problem to solve, which encourages critical thinking skills and promotes deep learning (Marton, 2018), both of which can engage important linguistic skills in the FL. Numerous models for PBL can be found, but a general summary of the key elements of PBL include that it (Davies & Kolmos, 2011):

- has complex problems at the center of the learning process;
- represents a constructivist approach where knowledge is constructed by the learner through his/her engagement with a particular problem and its solution;

- is student centered—earning is self-directed;
- supports critical thinking;
- has teachers' role as a supervisor and facilitator of the learning process;
- is based on students working and learning in teams which requires development of team and communication capabilities; and
- assists learners in their developing of cognitive and metacognitive skills through an emphasis not simply on the product but also on the (learning) process.

According to Bauman (2004) the increasing degree of complexity in societies challenges educational practices, making it necessary to reconsider learning outcomes so that they match what is needed beyond the classroom. It is necessary to support students not simply in becoming experts within a particular discipline but also in being able to move through multiple, complex scenarios to solve intricate and pressing problems. Putting society's problems at the center of education (Domik & Fischer, 2010; Fraser & Greenhalgh, 2001; Ivanitskaya, Clark, Montgomery, & Primeau, 2002; Little & Hoel, 2011; Marton, 2018) reveals their interdisciplinary nature. Thus, rather than supporting content learning of a single discipline, the problem-based approach puts the problem to be solved before the mechanism and tools to solve it in the search for a solution. Interdisciplinary learning finds its perspective in learning in the constructivist paradigm and is concerned with how concepts are interrelated and how knowledge is constructed beginning from its complexities (Fraser & Greenhalgh, 2001).

PBL has been used in engineering fields of different specialties. Hsieh and Knight (2008) compared problem-based learning and lecture-based learning in library instruction for first-year engineering students, for example. In empirical evidence they found that problem-based learning was an effective teaching method for students in this field, and concluded that it leads to better outcomes for the learning styles of engineering students. PBL has also been hailed as an effective approach to languages for specific purposes (LSP) courses as a way to develop diverse foreign language skills while honing social competencies desirable for teamwork and critical thinking skills, as Kosel et al. (2005) show when they detail their application for PBL learning to English for various disciplines, including mechanical engineering, at the secondary and tertiary level.

Adding the element of problem-solving and hence higher-level cognitive skills to task-based language learning, problem-based learning is a process-oriented approach. It stimulates the development of all language skills: speaking (e.g., through the exchange of information among group members and sustained monologues), reading (e.g., for gist and for specific information), listening (e.g., to other group members while exchanging information, at presentations), and writing (e.g., minutes, notes, a final report) (Kosel, Celinšek, Kuštrin, Djurić, Jarc, & Godnič Vičič, 2005 p. 1).

Central to PBL and this model, which is detailed further in the methodology section, is the problem to be solved. It is not easy to create a proper problem for classroom use, and for this reason, noting that an effective problem is the essence of problem-based learning, Mohammad Zamry, et al. (2012) developed a teaching technique for crafting PBL problems based on the experience of implementing PBL at Universiti Teknologi Malaysia (UTM), in a *Process Control and Dynamics* course, a chemical engineering course taken by third-year undergraduates. They reduced the criteria of effective PBL into five main principles, which were aligned with the objectives of using problems for learning.

1. The problem must be motivating, and "authentic and realistic, if not real" (Mohammad Zamry, Khairiyah, Nor Farida, & Syed, 2012, p. 379).
2. The problem should be constructive and integrated, with the outcome connecting to students' previous knowledge, but requiring them to stretch to develop new knowledge.
3. It should have in this sense proper complexity.
4. The problem should promote self-directed learning that is impactful, stimulating interest and motivation.
5. The problem should promote critical thinking and metacognitive skills, where students recognize that although many solutions may be possible, it is feasible to find a best solution for a given context (Mohammad Zamry, et al., 2012, pp. 380–381).

3 | METHODOLOGY

3.1 | Objectives

Our previous needs analysis showed a lack of graduating engineering students with sufficient intercultural skills to meet professional challenges, and an academic requirement to teach skills in intercultural competence as a cross-curricular competence in foreign language. To treat these gaps, as a first objective, we developed and piloted an effective PBL problem around a cultural critical incident for design engineers to solve in order to work intercultural competence as well as primarily productive linguistic skills in an English for specific purposes (ESP) course in industrial design engineering. Although critical incidents have been used for teaching intercultural competence and problem-based learning has been utilized in engineering studies (Nielson & Kolmos, 2010), we know of no attempt that has been made to marry these for focusing on intercultural competence and language in engineering. Secondly, to treat the lack of cultural awareness which was observed in the in-class needs analysis, we will examine through a quantitative opinion questionnaire in pre and post-phases whether students' beliefs about cultural factors change after working on a cultural incident problem.

To summarize, the research objectives were:

1. To develop and pilot an effective PBL problem around a cultural critical incident for design engineers to solve.
2. To examine students' beliefs on cultural factors in design before and after their critical incident PBL experience to see if any changes are observed.

3.2 | Participants

The population under study were third and fourth year students (aged 19–25) enrolled in the course *Multimodal Communication in English*, an optional course for undergraduates in the Industrial Design and Product Development degree at a public university in Spain. This course and its participants were chosen because the course treats both language and cultural aspects, since it is instructed in English and offers a module in cultural considerations for design components. These students were also selected over those in the *Technical English* course because they enrolled in the course voluntarily, which meant that they had some vested interest in continuing their English studies. Ten students, all of whom were enrolled in the above-mentioned degree and who made up the class total, participated in the project as an obligatory class assignment. Of those ten, six were men and four were women, all being native, Spanish monolinguals with origins in Spain. These students had already taken core field subjects like: *Design Expression I and II*, *Computer Aided Design (CAD)*, *Design Labs*, *Design Methodology* and *Materials*, and so they were capable of visualizing and preparing a product design for a given market, which was the principal task in the PBL problem here. In terms of English level, students generally come into the program with a low to high intermediate level of English, having taken the core course *Technical English* in their second year.

3.3 | Instruments: opinion questionnaire

In order to understand what students already thought of the concepts at hand before beginning, and to observe if their perspectives changed after doing the project, we designed and implemented a simple opinion (n = 7 items) questionnaire to examine their views on the importance of different factors in product design, including: product attributes (ergonomics and technical aspects), customer value of product, customer rights and legislation, cultural factors, reusability, and sustainability. Students were asked to rate the importance of each factor in the following manner:

How important are these factors when designing a new product?

1 = Not very important, 2 = Somewhat important, 3 = Unsure, 4 = Important, 5 = Very important

1. Product attributes

Environmental impact

1 2 3 4 5

The PBL project took place over a period of 4 weeks in the class (see Table 2 for general chronology) and this questionnaire was issued at the beginning of that period, before students started their readings in the pre-PBL phase, and then a week after they finished the PBL project, to determine if their opinions had changed after working on the cultural problem. We allowed a week to pass after finishing the PBL project to discourage memory recall and to provide some distance from the conversation on culture in general in order to access more authentic responses.

3.4 | Materials and approach: PBL critical incidents

3.4.1 | Problem creation

Following Mohammad Zamr, et al. (2012) and their five principles of problem creation for engineering PBL, we began with the context of a critical incident from a product design scenario, similar to those previously established by Van Bossuyt (2009) where one or more cultural factors create conflict for users because the intended use of a product design is muddled or lost. First, we studied the cultural scenarios from Van Bossuyt, which included such products as air fresheners and remote controls, and looked for other product CI scenarios that would be interesting and suitable for the students in question. We chose a scenario that had clear and broad cultural implications: an infant high chair. Since all cultures must eat, but different cultures group together to eat in different ways, this was an appropriate product for discussing culture in design. The choice of a child's seat seemed to be a useful problem given its everyday presence for many families all over the world of various origins and customs. It was also a relatively simple product to design in terms of its technical considerations and materials. We submitted the scenario to Mohammad Zamry, et al.'s (2012) model, as well as to Hiller's definition for what constitutes a critical incident, resulting in Table 1.

3.4.2 | Design of PBL steps

As discussed in the theoretical framework, problem-based learning necessitates progressive steps designed to maximize critical thinking through group discussion in order to create a solution to the problem at hand. This process also clearly optimizes linguistic practice in a communicative framework. The PBL task here was designed according to Kosel et al.'s (2005) 7-step model for applying problem-based learning to language for specific purposes (LSP) courses in tertiary education, detailed in Table 2. To this model we added two additional steps for preparing students for the linguistic work they would do for abstract writing, as well as the theoretical work they would do on culture in product design. They undertook this work in class a week prior to beginning the PBL assignment (see again Table 2 for a description and overall chronology).

3.4.3 | PBL problem packaging: The assignment

The assignment given to students centered around an authentic task pertinent to the students: writing an abstract with appropriate English for an engineering conference to take place the following year in a nearby European country. Students' handouts first introduced the concept of cultural research in engineering as a line of interest for the conference organizers, connecting this to what they had seen in class the previous week in their preparatory lessons

TABLE 1 PBL problem design

Step	Description
Learning Outcomes	It is expected that the students are able to: • Identify cultural factors important to the product design of an infancy-to-youth high chair • Identify what needs to be done to approach this design problem in an ideation stage • Write a conference abstract in English using appropriate language and format
Duration	4 weeks (1 week preparatory phases, 3 weeks PBL project) 16 class hours; 6 out-of-class hours
Level of Difficulty	Intermediate: Ideation of an infancy-to-youth high chair that promotes sustainability and considers cultural factors in design creation
Type of Problem	Authentic: the students prepare an actual conference proposal to submit to a design conference for the next year.
Scenario	3rd and 4th year students will prepare a paper proposal for an international design engineering conference to attend the next year.
Demand	Written academic paper proposal (Abstract) with standard format, including bibliography
Resources	Bibliography Previous product analysis Guidelines to complete the practice Sample abstracts for product engineering Questionnaire Template with prompts in student handouts
Packaging the problem for presentation	Class assignment with direct reference to a conference for authenticity, showing students conference website and discussing the possibility of attending as a class.
Critical Incident criteria match (Hiller, 2009, p. 1)	Assumption of normality: American assumes high chair bought on-line will be appropriate for Japanese friend. Collision: traditional tables and thus chair heights are lower in Japan than in the USA, so that the high chair is not functionable for that setting.
Prior knowledge	Students had been reading about cultural critical incidents in product design in class before the assignment, as well as doing a workshop lesson on how to write conference abstracts in English (preparatory phases.
Language skill focus	Oral: 1. giving opinions and group negotiating (fluency) 2. public presentations (signposting, register) Written: 1. Genre structure: scientific abstracts (titles, intro, background, problem, proposal, methodology, key words) 2. Passive and it structures 3. Discourse markers (sequencers, firstly, then etc., etc.) 4. Field lexicon for design engineering 5. Overall register (formal/academic)

on culture and abstract writing. This context then represents an important linguistic component to the PBL project: writing an abstract with an appropriate register and format which used determined grammatical structures as well as vocabulary for the field.

Once students understood the context, an academic conference proposal, they were then presented with the cultural critical incident which formed the base for their proposals, where a misunderstanding around cultural factors produces a conflict for the product user, in this case an American client who bought a high chair online for a Japanese friend, whose tables are not quite as tall as American tables. They are asked to ideate a high chair taking these and any other cultural factors they deem necessary into consideration for their abstract proposals in the line of culture in product design. The final product focused on students' productive skills in writing and speaking: (1) to produce a

TABLE 2 PBL steps adapted from Kosel, et al., 2005

Culture in Design Project: An Infancy to Youth High ChairPBL Steps and Chronology			
Chronology	**Purpose**	**Activity**	**Min.**
Prep 1 Week 1	To get a pre PBL opinion on design factors. To prepare students for concept of culture in product design.	1. Students take Pre PBL opinion survey on Design Factors. 2. Students read parts of Van Bossuyt's paper (2009, pp. 4–9) cultural scenarios in design, answered questions, and discussed these in class. 3. Out of class work: on the virtual platform, students discuss readings, and watch a video on culture in design (Maats, 2016).	100; 60 HW
Prep 2 Week 1	To prepare students for writing abstracts in English (vocabulary, register, structures)	Students read three abstracts for design engineering, (Williams, 2007, see Annex 5) identifying their main parts, which are divided into: Title, background to problem, problem, proposed solution, methodology, innovation/ field contributions. They identify register, vocabulary and grammatical structures key to this genre (Table 1).	100
PBL Step 1 Week 2	Making the problem clear.	Each group of students is given the cultural incident problem to read through and understand. They are shown the conference website and presented the idea of doing a group abstract for the research line on culture and design to present there.	15
PBL Step 2 Week 2	Formulating questions and queries.	A brainstorming session results in the production of ten questions they need to examine related to the problem of ideating a infancy-to-youth high chair for Japanese and American cultures.	15–30
PBL Step 3 Week 2	Identifying current knowledge and learning needs	The group discusses what the group members already know about the questions, and what they need to find out to complete their high chair proposal.	15
PBL Step 4 Week 2	Structuring ideas	Drawing a mind map, the students visually group ideas together and relate these to the research questions.	30
PBL Step 5 Week 2	Formulating learning aims and distributing tasks to group members.	Each group member is assigned a research task to find further information about what needs to be known to ideate the high chair, to be presented to their whole group in the next class.	30
PBL Step 6 Week 2-3	Individual activities and research	The research continues outside the class so that students can consult a variety of sources and find information for unknowns of Step 5.	120 HW
PBL Step 7 Week 3	Discussing, evaluating, writing	Students try to decide if they have enough relevant information to defend their solution to the problem, where a positive answer leads to the abstract writing stage and a negative one to additional research. Writing was begun in class in large papers so as to be a group task and include oral as well as written productive skill practice.	50; 120 HW
PBL Presentations Week 4	Finish abstract writing Presenting project results	Students finish their abstracts and prepare presentations. In the last class, they present their group work to the rest of the class and we have group discussions about each.	100; 60 HW
Post PBL Week 5	To test students opinions on Design factors	Students again take Post-PBL opinion survey on Design Factors one full week after doing their abstract presentations.	15

written abstract in English; and (2) to make an oral presentation of the abstract proposal to the rest of the class followed by a Q&A session with other students.

4 | RESULTS AND DISCUSSION

4.1 | Objective 1: PBL project

4.1.1 | Project preparation steps: culture in design

In the preparatory phases, students were introduced to the idea of culture in design and engaged with several resources on the subject in and out of class (see Table 2). This was positive for their linguistic development as they engaged in discussions in both written (virtual platform forums) and spoken (class discussion) formats in English, using language for negotiation and giving opinions with appropriate lexical inclusions for the field of design. In terms of IC, at first, students responded somewhat reluctantly to the importance of culture in product design, and a good deal of interesting debate was had over the readings and video that extended ideas on the reach of technology. Students' initial reluctance seemed to stem from a persistent underlying assumption, echoed in the needs analysis discussions, that most people have the same needs, and meet them in similar enough ways, which was contrary to the readings done in class. The preparatory phase revealed students' understanding of the need to design products that function from a technical, ergonomic, and aesthetic perspective which they saw as ultimately universal, i.e., somehow applicable to all cultures. This may indicate a more localistic viewpoint over a truly global one, so that students might recognize cultural differences on the surface but minimize these in terms of their global importance (Bennett, 2013). This would occur in a low-intermediate, and more ethnocentristic stage of development in intercultural competence (Bennett, 2013).

4.1.2 | PBL steps 1–5

In these stages, as a continuation of the theme of culture in design, students were introduced to the PBL central problem, packaged in a cultural critical incident. They were also informed about the culture-in-design research line of the conference and the abstract proposal assignment. In groups they discussed the cultural expectations present in the critical incident and what those meant for the product, an infancy-to-youth high chair. In the second step, they created 10 essential questions together they would need to answer from a design perspective to ideate a high chair for both cultures, which can be read in Figure 1 in the bottom-left corner. Linguistically, they worked on oral fluency as they talked together, using in particular question formations and design engineering vocabulary (*benchmarking*, *materials*, *security*, *product size dimensions*, *stackable parts*, *removable parts*, etc.).

Some examples of students' questions were:

1. What is the maximum height of the tables in each culture?
2. Could materials be ecological?
3. What materials are durable, but good for the environment?
4. What is more important, the baby's comfort or the baby's security?
5. Is it possible to take it down and set it up easily?
6. How do babies sit in each country?

The questions students developed were appropriate for an ideation stage. They were diverse, ranging from concrete cultural considerations to technical considerations using language that design engineers need in the field. In step

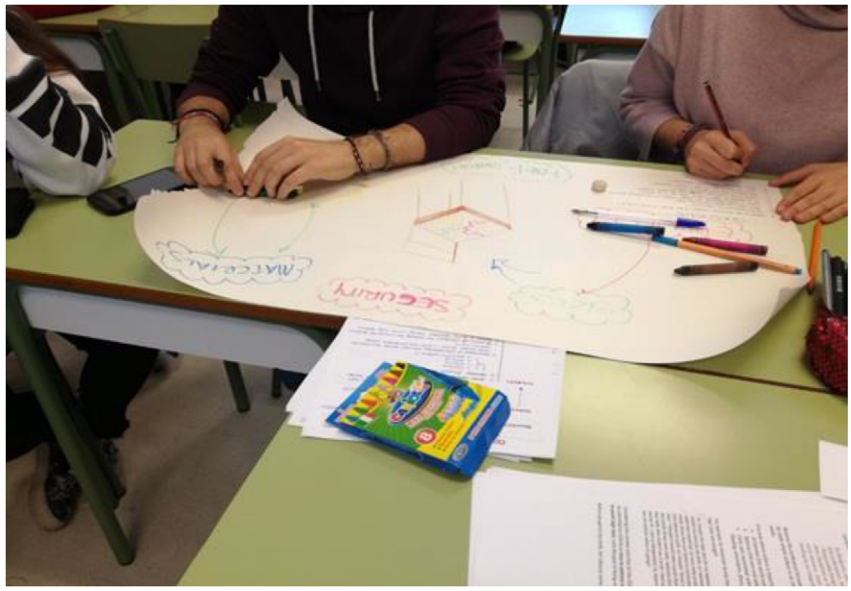


FIGURE 1 Students working on PBL step 2: creating essential questions for ideating a high chair for American and Japanese cultures [Color figure can be viewed at wileyonlinelibrary.com]

4, students were asked to connect the work they had done up to that point in a mind map. An example of student work for step 4 is shown in Figure 2.

In the mind-map above, one can observe that students were able to identify several cultural components important in the design of an infancy-to-youth high chair. Specifically, they looked at culturally appropriate colors, living standards, national legislation for baby products, standard chair heights, and daily routines in American and Japanese cultures. They also considered sustainability as they inquired into the biodegradability of products used. Students linked these questions to major areas, such as benchmarking and materials. Once these mind-maps were finished, students moved on to step 5, which was to determine what tasks needed to then be done to get the information necessary to ideate a high chair and write the conference proposal.

4.1.3 | PBL Steps 6–7

In step 6, students did individual research outside of class with the goal of reconvening in the next class to share their information. Some groups brought more detailed information to share, (for example, standard table height dimensions for Japan and the USA). All groups deemed themselves ready to begin writing a draft proposal after the individual information sharing session, which was the initiation of step 7, the actual writing phase. In Figure 3, one group is working on their abstract draft, while referencing one of the abstracts studied in the preparation phase.

Students were asked to write their drafts in large font on continuous paper so that all group members could see and comment on the progress, as can be seen in detail in the image below. This allowed for a very visual revision phase, where anyone in the group could cross out and add to the draft as it was created. This was helpful to students' linguistic progress, since writing, often an individual task, here became collaborative and active, making it both a speaking and writing task. Part of this collaboration included a concept revision phase, where students returned to the draft to highlight key concepts that were important to the conference theme which they wanted to emphasize. An example of draft changes is seen in Figure 4, where content emphasis is marked in green and yellow, and different individual's handwriting can be noted for draft wording changes.

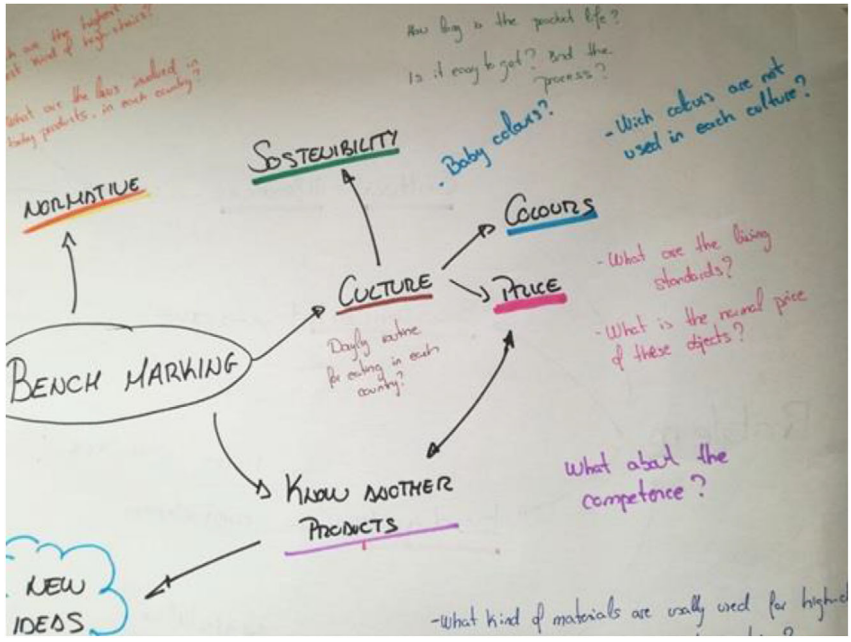


FIGURE 2 Step 4 Mind-map: connecting questions and concepts [Color figure can be viewed at wileyonlinelibrary.com]

FIGURE 3 PBL step 7: group begins draft abstract [Color figure can be viewed at wileyonlinelibrary.com]

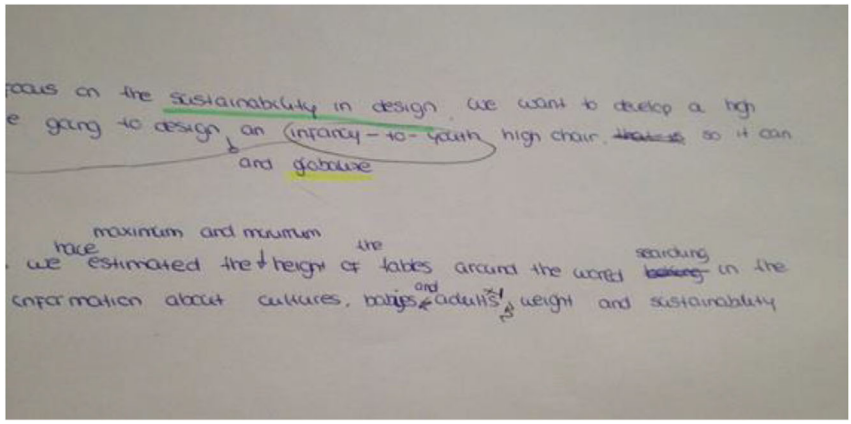


FIGURE 4 Group revision of draft in detail [Color figure can be viewed at wileyonlinelibrary.com]

4.1.4 | Post PBL: Final drafts

Students were required to turn in their conference proposals for their group 1 week after step 7 ended, so that they had some time to consider changes as a group and work on the final draft outside of class. In the finished product, the conference proposal, students' understanding of the problem underlying the critical incident was quite clear. One proposal read "not every culture has the same sitting habits. While in some cultures, people prefer to sit on the floor, others use different height (sic) chairs." Another proposal indicated that such differences, table heights, were important to the high chair's functionality, and should be considered when designing a chair that spanned more than one cultural market. Sustainability was also present in students' final proposals, as they considered: product life, heights for children up to 12 in the two countries (for considering the need to make the chair last into youth), as well as product materials. One proposal read "The solution is based on a series of bamboo blocks that can be stacked, generating different heights of chair (sic) … The reason why bamboo has been selected as the base material is the fact that is considered (sic) as one of the most sustainable materials, due to the easiness (sic) to get and the capacity to reforest its plantation."

In terms of linguistic improvement, all groups were able to successfully include some if not all of the areas worked on in the class given in the preparation stages on abstracts (see again Table 1), including: (1) structures for academic writing (passives and *it* phrases); (2) discourse markers (*moreover*, etc.); and (3) appropriate vocabulary (lexical items for the field like *benchmarking*, etc.). Some examples taken from student abstracts are shown in Table 3. An interesting result in terms of linguistic practice was the absence of sequencing discourse markers like *firstly*, which was discussed in the abstract-writing class session. Also, some errors were present with *it* structures and more direct language (first person plural, see Figure 5) were utilized, which were specifically discouraged in the class session on abstracts.

Finally, excepting the use of first person plural, the register of all the abstracts was quite appropriate. In terms of genre structure, all the abstracts followed at least the basic structure for abstracts (title, introduction, problem, solution) and two were quite complete in including background and other aspects discussed in the preparatory class session, an example of which can be seen in Figure 5.

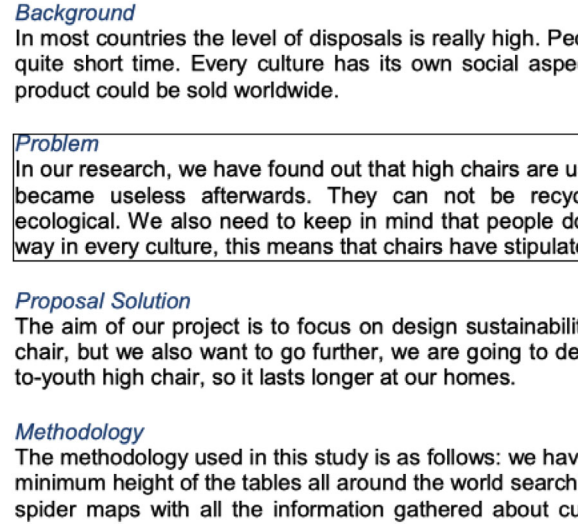
4.1.5 | Abstract presentations

Once the drafts had been revised and turned in as final, students presented their projects and ideas to the rest of the group in post-PBL (Figure 6). Although all students within their groups seemed very comfortable discussing their

TABLE 3 Linguistic work results in students' abstracts

	Examples:	Issues:
Passive and it structures	-"it is possible to continue using it" -"it's a solution that can be able (sic) for babies" -"it is considered" -"it is important to redesign" -"This design it (sic) could be a problem if"	-More direct language was used than recommend (our project, we recommend etc.) in all of the abstracts. -Some errors with *it* in doubling subjects
Discourse markers	-"Moreover, we analyze" -In addition. -"Thus, the methodology used" -"Furthermore"	Good use of markers to add information or indicate consequence. However, no sequencing markers were used, which was taught in workshop.
Design lexicon	-"modular system" -"stacked" -"environmentally friendly" "environmental damage" -"maximum height" -"sustainable materials" -"innovative product" -"removeable parts" -"affordable" -"non-toxic"	Appropriate.

FIGURE 5 Example of students' use of genre structure for conference abstracts [Color figure can be viewed at wileyonlinelibrary.com]



ideas in English, when it came time to present the proposals to the rest of the groups, in general the groups chose their perceived "most fluent" member as a spokesperson, which was not ideal for linguistic practice. After each presentation, the other groups gave feedback as to the most salient aspects of the different proposals, and at that point more students participated.

FIGURE 6 Group PBL abstract presentations and question and answer period [Color figure can be viewed at wileyonlinelibrary.com]

4.2 | Assessment

Students were evaluated for the different parts of the PBL process in such a way as to give weight to the process (steps 1–7, and preparation), as well as to the final products, which were the written abstract and the presentation. In general, content was valued over form, so that 60% of the grade on each area was designated to content inclusions and group processing and 40% to form or how that content was expressed in the students' English. Linguistic content was evaluated for accuracy most in the written abstract, where students were asked to include specific linguistic formulae (discourse markers, passives, etc.) taught in the preparatory steps prior to beginning PBL. Overall, students' group grades were made up of the following areas, which each included active group work as well as a concrete item to be turned in to the instructor:

- 10% Participation in class and in virtual forums for PBL preparation;
- 30% Brainstorming (mind-map) and research questions;
- 30% Written abstract; and
- 30% Oral presentation and group Q&A.

As a final note on assessment, all groups received a passing grade for the project, and one with particular detail received an A, while the rest of the group received Bs.

4.3 | Results: Objective 2: opinion questionnaire

Objective 2 examined if students' opinions on the importance of culture in design changed after completing a PBL project based on this. The opinion questionnaire was designed to examine students' beliefs about the importance of concrete aspects of design, in particular the importance of culture, before undertaking PBL and once they finished the PBL project. One can appreciate in Figure 7, student perceptions of the following aspects of design in terms of how important they deemed them to be, where 5 is very important and 0 is unimportant.

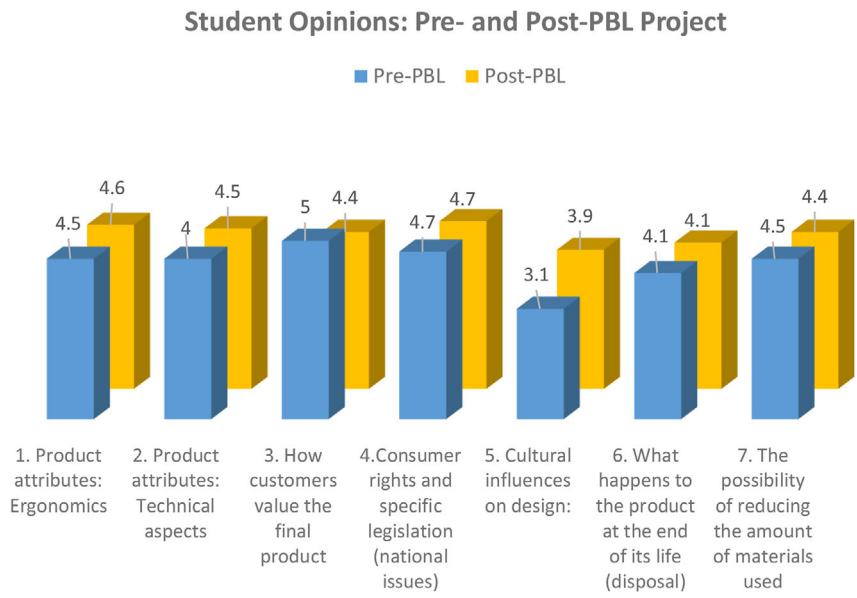


FIGURE 7 Student opinions on importance of factors related to design [Color figure can be viewed at wileyonlinelibrary.com]

In Figure 7 one notes that cultural influences on design is one of the lower-marking factors, both pre- (blue) and post-PBL (yellow). The highest-marked factor seems to be the factor concerning consumer rights and specific regulation. It is interesting that students did not find culture to be as important a factor in design as others after the PBL project, despite the clear focus on this in the unit. This may echo students' class and forum discussions throughout the pre-PBL steps when they were reading and debating cultural influences in engineering. In those preparatory phases, although they seemed to grasp the concept, teacher observation noted that they displayed a more localistic perspective over a truly global one, where remarks were oriented toward seeing most modern societies as universally similar, united by social media and technological devices (Internet, smart phones, etc.). This caused them to discuss cultures as mostly the same, united around similar needs. Again, this was despite the evidence in the readings, so that one might posit that they simply did not believe culture was the issue the authors discussed, or, to put it in Bennett's (2013) terms, they were at a low to intermediate point on an intercultural sensitivity development scale.

Student responses to the pre and post PBL questionnaire factors were further analyzed statistically using the paired sample *t test*, a parametric test in SPSS (version 20.0) to determine if any significant difference pre- and post PBL existed in the students' answers. The paired *t*-test compares the means of two related groups of data (paired, repeated, or matched variables), in this case comparing students' overall responses to the questionnaire before undertaking the project and then again after finishing the project, in order to determine whether there is statistical evidence that their means are different. We also undertook a paired differences *t*-test to compare individual items in the same way.

Although these responses reveal a quite positive tendency overall, significant results for the pre-PBL and post-PBL questionnaires were not observed for most items at the individual level, which may be due to the small group size in this case. It can be noted that overall students found *Customer satisfaction with the final product* to be the most important in product design (a 4.7 average for both pre and post-PBL), followed by *Ergonomics*, *Technical aspects*, and *Reducing materials*, all hovering around 4.4–4.5.

Since the factor customer value received the highest score from students, this was investigated further using paired samples in a *t*-test for the pre and post-PBL group opinions. As can be seen in Table 4 and 5, significant results (95% confidence) were observed when grouping students for the item *Customer value of the final product*, where students

TABLE 4 Customer value of the final product

	Mean	N	Std. Deviation	Std. Error Mean
How customers value the final product (prePBL)	5.00	10	0.000	0.000
How customers value the final product (postPBL)	4.40	10	0.699	0.221

TABLE 5 Customer value of the final product *t*-test

	Paired Differences							
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
How customers value the final product (prePBL) - How customers value the final product (postPBL)	0.600	0.699	0.221	0.100	1.100	2.714	9	0.024

ranked this factor as less important after the PBL project than before. Here the group average was 5 in the pre-PBL questionnaire, the highest marked item in the questionnaire, but it decreased to 4.4 in the post questionnaire.

Finally, a significant difference was observed in the pre and post opinions concerning cultural influence in design. In Table 6 we can observe that the two-tail difference between the pre- and post-PBL questionnaires for this item, with a 3.1 average response pre-PBL and a 3.9 average mark post-PBL, is less than 0.05. This indicates that the null hypothesis should be rejected and the differences in opinions in the pre and post-PBL responses to the cultural design factor are significant.

These results may point to the effect the PBL project had on the students, in increasing their opinion on the importance of cultural factors in design. This was the only item to experience upward changes in opinion in the post PBL questionnaire (only one other item increased, *ergonomics*, and only by 0.1 in the average group mark, which was not significant).

TABLE 6 Cultural influences in design

	Cultural influences in design (pre-PBL)	Cultural influences in design (post-PBL)
Mean	3.1	3.9
Variance	0.988888889	0.32222222
Observations	10	10
Pearson correlation	0.413356996	
Hypothesized mean difference	0	
df	9	
t Stat	−2.752988806	
P(T < = t) one-tail	0.011183595	
t Critical one-tail	1.833112933	
P(T < = t) two-tail	0.02236719	
t Critical two-tail	2.262157163	

This is an interesting change in student opinion. The PBL project students undertook was clearly posited within the context of its importance in classwork. In the preparatory phase, students read about different cultural conflicts resulting from product creations that did not contemplate cultural factors in design, as well as more theoretical texts on the importance of considering culture in engineering, and then proceeded to design a product based on such theoretical groundwork to resolve a cultural critical incident. That students' opinions changed post-PBL may show their willingness to reconsider this factor as important, and thus their openness to investigating it further, despite the fact that they did not consider culture as important a factor as others, such as *customer satisfaction*, given that it ranked the lowest-marked factor in both the pre- and post-PBL tests. This is positive for the pilot study overall, as it indicates that it had a positive effect on students by revealing the importance of investigating cultural factors in engineering.

5 | CONCLUSIONS

Language instructors in engineering programs are tasked these days with developing both students' linguistic and intercultural skills (Bridgestock, 2009). These skills are necessary for future engineers who aspire to find work in an increasingly globalized world, not only so that they can successfully navigate their future international teams, but also so that they can manage the increasingly complex work of engineering in a more interconnected world where people, their needs and cultures collide, despite the webs of technology and commerce that approximate them.

In this sense, at the heart of cultural relativism is the idea that people share the common needs of a species, though their perceptions of and acting upon these needs may be vastly different. This is a concept that is basic to intercultural awareness (Deardorff & Ararasatnam-Smith 2017). For effective engineering, it must also be translatable to what they engineer, since cultural factors may cause users to interact in quite different ways with products, as Van Bossuyt (2009) and Norman (2012) have shown. Critical incidents, often used in intercultural training, were chosen as an ideal way to demonstrate the sort of cultural conflict that can arise when products only work within one given context because of cultural considerations, considerations which should be previously weighed in design.

Students need to develop an awareness of these factors, while honing critical thinking skills and developing linguistically, and problem-based learning is an excellent methodology for doing so. While it has been used for teaching intercultural competence in the past, as well as for working engineering problems, no attempt had been made to marry these through the use of critical incidents. Through this methodology, which focuses on students' autonomy and constructivist learning, linguistic skills are also improved, as they must work in their foreign language through the various stages of PBL to create a group proposal and complete the larger task at hand, in this case ideating a sustainable, infancy-to-youth high chair for Japanese and American tables in the form of an authentic conference proposal abstract in their Multimodal Communication in English course.

In this study, the first objective was to design and pilot a cultural critical incident problem for use in an English for engineering course. Students' final products contemplated important cultural factors, and their discussions and preparatory work in creating essential questions and mind-maps throughout the PBL steps revealed their grasp of the basic concept of cultural difference, so that we can confirm that the approach, PBL based on critical incidents, is an appropriate way of working intercultural competence in class.

The second objective of this paper was to determine if students' opinions on the importance of culture in product design changed after working on this through PBL. The results showed that students' responses were significantly higher for cultural factors after completing the PBL project. This shows that the project had a positive effect in at least raising students' awareness about cultural factors in product design, which is positive for overall intercultural competence, even if they did not see these as important as other factors in design, such as customer value, which was the highest marking item on the opinion questionnaire. Despite doing readings on the overlooked but important role of culture in design, and then a project that highlights how such cultural differences and their complexities may play out in design, students still rated this factor behind all others, which is interesting. Students' response again may point to a low to middle level of cultural awareness, where students recognize cultural differences, but may minimize these

or accept them only superficially. Such low-to-middle levels of cultural awareness could be a harbinger of the need for more thought on how to best lay the groundwork for the importance and effect of cultural differences. Students' opinions did change however, post PBL, so future instructors wishing to effectively integrate intercultural skills and language skills in engineering programs can take note of this change, since it shows that student awareness of cultural factors can be increased with PBL work focusing on intercultural critical incidents.

FURTHER RESEARCH

Future work in the area should explore how to develop students' intercultural awareness toward greater ethnorelativism (Bennett, 2013). This might be done in a longer project with more reflective stages. In addition, one drawback to this study was the impossibility of actually creating the high chairs as students have done with other design projects. A longer project would allow for the PBL problem to move on to the physical creation of a product, taking students beyond the ideation phase to development and production, and allowing them to experience more concretely the different cultural adaptations of the physical object. Finally, establishing and maintaining communication with engineering students in other parts of the globe as part of the project work could more adequately highlight how such cultural differences play out in their respective scenarios.

DATA AVAILABILITY STATEMENT

Data available on request from the authors.

PEER REVIEW

The peer review history for this article is available at https://publons.com/publon/10.1111/ijal.12370.

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