

Understanding Dimensions of Disciplinary Engineering Culture in Undergraduate Students

Homero Gregorio Murzi Escobar

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Lisa D. McNair, Chair

David B. Knight

Thomas L. Martin

Marie C. Paretti

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Blacksburg, Virginia

Keywords: Disciplinary Culture, Engineering Culture, Engineering Education, Hofstede, Mixed
Methods

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ABSTRACT (Academic)

The purpose of this study is to understand how engineering students perceive the patterns of culture at the disciplinary level using Hofstede's constructs (power distance, individualism, uncertainty avoidance, and masculinity). The methodology design for this study is mixed methods. More specifically, the design of this study is an explanatory sequential design that begins with the collection and analysis of quantitative data from a version of Hofstede's survey developed by Sharma (2010), followed by subsequent collection and analysis of qualitative data, with the qualitative analysis being informed by preliminary results from the initial quantitative phase. Results from the quantitative study led to a review of the literature regarding Hofstede's main critiques and how other authors have successfully implemented his model in different contexts, and qualitative data collection with semi-structured interviews with undergraduate students. There are three aims of this study, which are addressed and presented in three separate manuscripts. The first aim (Manuscript 1) was identifying if Hofstede's theory of dimensions of national culture can map to academic disciplines. Results from surveying 3388 undergraduate students provided scores on Hofstede's dimensions for each major. Responses matched the national culture of the students rather than the disciplinary culture; therefore, Hofstede's theory didn't map to explain cultural differences in academic majors. The second aim (Manuscript 2) of this study was to review the extensive available literature regarding the critiques of Hofstede's model and its implementation in different settings. Results provided with conceptual, and methodological critiques and misuse of his theory that allowed us to understand the value of his model to understand cultural differences at the national level, as well as the value of the dimensions to inform our qualitative research design. The third aim (Manuscript 3) of this study was to explore students' perceptions of disciplinary engineering culture and how it compared to other disciplines using a qualitative interview protocol that provided rich findings that complement the quantitative results. Results from interviewing 24 students in industrial and systems engineering, electrical and computer engineering, marketing, and industrial design provided with valuable information on how students perceive their disciplinary culture in terms of what it is valued, how they learn, how it is taught, why they learn, how it is going to be used in the workplace, and the reason for select the major. Implications for research and practice in the engineering education field are provided to inform how to make decisions on engineering curriculum, and engineering classrooms and try to find ways to improve some of the issues that engineering education has been facing for the last decades.

Keywords: Disciplinary culture, engineering culture, engineering education, Hofstede, mixed methods.

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Homero Gregorio Murzi Escobar

ABSTRACT (Public)

Culture shapes the way we behave and act. Understanding culture at any level can bring several benefits to help us better perform in different contexts. However, understanding culture can be very complex. The purpose of this study is to understand how engineering students perceive the culture of their academic discipline. To understand the disciplinary culture of engineering I used Hofstede's framework of dimensions of culture. He developed four dimensions to measure how people define their culture (power distance, individualism, uncertainty avoidance, and masculinity). The methodology design for this study is mixed methods. It begins with the collection and analysis of quantitative data from a version of Hofstede's survey developed by Sharma (2010), followed by subsequent collection and analysis of qualitative data, with the qualitative analysis being informed by preliminary results from the initial quantitative phase. Results from the quantitative study led to a review of the literature regarding Hofstede's main critiques and how other authors have successfully implemented his model in different contexts, and qualitative data collection with semi-structured interviews with undergraduate students. There are three aims of this study, which are addressed and presented in three separate manuscripts. The first aim (Manuscript 1) was identifying if Hofstede's theory of dimensions of national culture can map to academic disciplines. The second aim (Manuscript 2) of this study was to review the extensive available literature regarding the critiques of Hofstede's model and its implementation in different settings. The third aim (Manuscript 3) of this study was to explore students' perceptions of disciplinary engineering culture and how it compared to other disciplines using a qualitative interview protocol that provided rich findings that complement the quantitative results. Results from surveying 3388 undergraduate students provided scores on Hofstede's dimensions for each major. Responses matched the national culture of the students rather than the disciplinary culture; therefore, Hofstede's theory didn't map to explain cultural differences in academic majors. Results provided with conceptual, and methodological critiques and misuse of his theory that allowed us to understand the value of his model to understand cultural differences at the national level, as well as the value of the dimensions to inform our qualitative research design. Results from interviewing 24 students in industrial and systems engineering, electrical and computer engineering, marketing, and industrial design provided with valuable information on how students perceive their disciplinary culture in terms of what it is valued, how they learn, how it is taught, why they learn, how it is going to be used in the workplace, and the reason for select the major. Implications for research and practice in the engineering education field are provided to inform how to make decisions on engineering curriculum, and engineering classrooms and try to find ways to improve some of the issues that engineering education has been facing for the last decades.

Keywords: Disciplinary culture, engineering culture, engineering education, Hofstede, mixed methods.

Dedication

To Homero and Gabriel

Thank you for teaching me what is valuable in life. Thanks for all your laughs, deep questions, and patience during the difficult times, this was a sacrifice for all our family, and you guys teach us every day how to enjoy life and be happy with the little things.

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1. Chapter 1. The study

1.1. Introduction

Culture represents a set of values and norms that dictate how people behave, interact with each other, learn, shape their personality, and live (Hofstede, 1980; Namenwirth & Weber, 1987; Smircich, 1983). Several groups can be described as having a culture. Minkov and Hofstede (2013) affirm that the study of culture is the study of meanings. There are elements like symbols, values, norms, beliefs, behaviors, attitudes, self-perceptions, cognitive abilities, and stereotypes (Minkov & Hofstede, 2013) that have meaning to specific groups, and through these common elements groups share the same culture. Culture can be studied at different levels, including the national level, organizational level, race level, sports level, regional level, and even academic level. Minkov and Hofstede (2013) define culture as a group-level stable scientific construct that it is important to be measured in order to understand different aspects of the groups the culture is being shared by. In order to better understand the engineering discipline, it is important to understand its culture. Engineering disciplinary culture shapes the way students understand how to become a professional engineer, how to relate with their professors and peers, how to approach learning engineering topics, and how to apply their undergraduate knowledge in engineering settings. Understanding engineering disciplinary culture can provide valuable information to the engineering education field in both research and practice. First, it can provide information to expand what is known about engineering academic culture. In addition, it can provide information to improve engineering curriculum, to develop effective mentoring programs in engineering schools, to improve engineering classrooms' environment, and to help administrators make effective decisions

regarding engineering programs, faculty development, orientation programs, and policies that will have a direct impact on improving students' experiences. For example, Sheppard, Pellegrino, and Olds (2008) affirm that the primary "customer" in engineering education is the student, meaning that engineering schools should be developed to satisfy students' needs. Thus, one of the main goals of the field must be to understand and know how the students define the way they experience their discipline, in terms of how they learn, what things they believe are acceptable, how to behave in the specific discipline, and how to collaborate and interact with others. The authors further explain that in order to create better and more effective educational experiences it is necessary to understand who are the students, where they come from, how they learn, what motivates them and stimulates their interests, and how they perceive and conceptualize their discipline (Sheppard et al., 2008). I argue that understanding disciplinary culture in engineering majors can provide a better understanding of: (i) how students develop the skills they consider are necessary to operate in their majors, (ii) how students interact with peers from their same discipline, (iii) how students interact with figures of authority (i.e. faculty members), (iv) how students operate across disciplinary boundaries, (v) how students learn in their discipline, and (vi) how students perceive their discipline.

1.2. Statement of the problem

The Accreditation Board for Engineering and Technology (ABET), in accordance with industry and academic leaders, has established that engineering schools should produce engineers who are problem solvers, creative thinkers, globally aware, and able to work effectively in interdisciplinary teams (Shuman, Besterfield-Sacre, & McGourty, 2005; Terenzini, Cabrera, Colbeck, Bjorklund, & Parente, 2001; Woods, 1997). Many of the efforts regarding improving engineering classrooms in terms of the required skills that

industry demands in engineering students are seen as a sacrifice in the development of discipline-specific problem-solving skills (Clough, 2004; Tryggvason & Apelian, 2006).

According to Vest (2008) engineers in their daily work face the stress of competing in the fast-paced world of change that is known as the “knowledge-based global economy of the twenty-first century” (p.235). The engineering field is expected to solve global problems, to help countries improve their economies with leadership in innovation, and to make the world more connected and accessible (Mihelcic, Phillips, & Watkins Jr, 2006; Redish & Smith, 2008; Rugarcia, Felder, Woods, & Stice, 2000; Sheppard et al., 2008; Tryggvason & Apelian, 2006; Vest, 2008). There is a need that engineering education improve the engineering field by providing with the graduates able to fulfill those needs; however, providing the design and delivery of quality engineering education that fulfills industry and societal needs is a very complex task (Sheppard et al., 2008). This reality requires a shift in the way engineering is perceived. Understanding engineering disciplinary culture can provide information about the root of this problem.

Engineering education has been facing several core issues for more than three decades. Since the 1990's engineering education researchers like Denton (1998), Seely (1999), and Rugarcia et al. (2000) have been presenting research about the need for a balance of theory and practice, the need for engineers that satisfy industry needs, the need for more inclusion and diversity, and the need for engineers with an ability to collaborate with other disciplines, concerns that apparently have not been totally addressed nor improved yet. For example, Redish and Smith (2008) analyzed what several authors said engineering students need to learn. The authors explained that in 1918 the Mann Report was developed and pointed out issues with “overcrowded curricula, need for integration of theory and practice, the need for better student retention, difficulty in assessment,

professional development of faculty, and development of engineering skills” (p. 295), issues that engineering education is currently facing. It seems that engineering education has been shifting as a field, undergoing an evolution of the engineering disciplinary culture. However, this shift has not fully impacted engineering classrooms yet.

Despite the evolution of the engineering profession and the fact that students have changed over time, faculty members keep teaching as they were taught (Chubin, Donaldson, Olds, & Fleming, 2008; Tryggvason & Apelian, 2006). Furthermore, several curricular changes have been implemented in the last 30 years, but those changes are relatively modest considering that the core structure and the programmatic content of most engineering programs remain very similar to what it used to be back in the sixties (Tryggvason & Apelian, 2006).

Redish and Smith (2008) explain how several studies in engineering education have focused on explaining what those skills are. The authors outline some of the most important reports like the 1997 Engineering Futures by Boeing, the Engineer of 2020 report, The National Engineering Education Research Colloquies, and the Commissioned papers for the National Center on Education and the Economy, including, “Rethinking and Redesigning Curriculum, Instruction and Assessment.” The authors affirm:

These studies are converging on a view of engineering education that not only requires students to grasp traditional engineering fundamentals, such as mechanics, dynamics, mathematics, and technology, but to also develop the skills associated with learning to imbed this knowledge in real-world situations. This not only demands skills of creativity, teamwork, and design, but in global collaboration, communication, management, economics, and ethics. (Redish and Smith, 2008, p. 295)

Part of the problem is that engineering classrooms were designed in the early years to be very effective in making students able to perform routine and repetitive calculations

(Rugarcia et al., 2000). Nevertheless, engineering classrooms in modern days are required to educate students that develop skills like teamwork, creativity, and problem solving (Jesiek, Zhu, Woo, Thompson, & Mazzurco, 2014; Redish & Smith, 2008; Terenzini et al., 2001). In order to meet those requirements, the U.S. Accreditation Board for Engineering and Technology (ABET) developed a set of criteria that not only included the “hard” traditional skills, but also included a set of “professional” skills (i.e. teamwork, creativity, problem solving) that every engineering school should be developing (Shuman et al., 2005). As the April 2014 special issue of the *Journal of Engineering Education* suggests, approaches to develop those skills require transforming engineering education, including promoting changes in curriculum and pedagogy, rewriting promotion and tenure policies, and acknowledging teaching excellence (Besterfield-Sacre, Cox, Borrego, Beddoes, & Zhu, 2014); using experiential exposure to innovation so students can take control of their careers (Weilerstein & Shartrand, 2008); promoting collective efficacy and value beliefs to improve individuals’ competence (Matusovich, Paretti, McNair, & Hixson, 2014), and using local data to bridge the research-to-practice gap and design plans that accelerate the adoption of effective teaching practices (Matusovich et al., 2014).

Matusovich et al. (2014) affirm that understanding collective beliefs and values are essential in supporting this change. Therefore, it is necessary to understand disciplinary engineering culture. As Godfrey and Parker (2010) note, calls to address improvement in engineering education through a cultural lens date back at least to the mid-1990s and encompass studies of national cultures, institutional and campus cultures, faculty cultures, gender and cultures, and more. Culture has been a particularly prominent framework used in relation to underrepresented groups, particularly women, in engineering; lack of diversity in the field is often attributed to the masculine, individualistic, and function-oriented culture

of engineering (Dryburgh, 1999; Faulkner, 2000, 2007; Henwood, 1998; Kunda, 2009; Powell, Bagilhole, Dainty, & Neale, 2004; Tonso, 2006, 2007)

Therefore, evidence is showing that there is a problem in engineering education that has been addressed by different researchers in the field from epistemological, pedagogical, curriculum development, systemic, and instructional perspectives among others. However, there is little information on how to understand engineering disciplinary culture in academic settings.

This research purpose is to explore how undergraduate engineering students perceive the dimensions of engineering disciplinary culture. By understanding how students define their disciplinary culture, it will be possible to have a better understanding when making decisions to create different strategies that make engineering classrooms more effective developing the required skills, and more welcoming and attractive. In addition, researchers and practitioners can productively combine such knowledge of students' perspectives on research-based instructional strategies that are becoming more common in the field. Understanding disciplinary cultures can support educational success by understanding the behaviors in the engineering discipline that “extend beyond the cognitive to the ability to play the game of social interaction” (Foor et al., 2007, p.104).

Although several studies inform the needs of the engineering field and the things that need to be changed in engineering education, and despite the fact that engineering professors are increasingly more involved in educational research, teaching workshops, and the ASEE conferences, Rugarcia et al. (2000) affirm that engineering schools continue to be slow in implementing those changes. In my own experience as a faculty member in an industrial engineering department, I was faced with most of those problems. Therefore, my motivation behind this study is to understand that reality from the cultural perspective. I

understand that there are several ways to improve engineering classrooms, and understanding disciplinary cultures in engineering majors is not the only solution; however, disciplinary cultures shape the way people behave, act, communicate, and operate in a discipline, because those elements are the main elements of a measurable culture (Minkov & Hofstede, 2013). According to Kezar and Eckel (2002) before implementing any process of change in higher education institutions it is important to first understand the institutional culture. According to the authors culture provides change agents with a clear understanding of “why and under what circumstances” (p.5) some strategies work in a particular academic program at a particular time, because the information that understanding culture provides goes beyond idiosyncratic observations to provide information that balances the level of detail with the level of abstraction required to guide change (Kezar & Eckel, 2002). Kezar and Eckel (2002) affirm that change strategies seem to be successful if they are culturally coherent or aligned with the culture of the institution. I argue that after understanding behaviors, norms, values, and culture, it is easier to implement and promote change that is more likely to succeed. As Godfrey and Parker (2010) suggests, the analysis of culture is an interpretive science in search of meaning, rather than an experimental science in search of law. The search for meaning and sources regarding how engineering students understand their majors can critically question current practices in engineering education and strengthen efforts to improve curriculum, research, and policy.

In conclusion, I argue that understanding disciplinary cultures in engineering majors can provide valuable information for the engineering education field that can help make specific informed decisions to improve engineering curriculum, and engineering classrooms and can help to better understand some of the issues that engineering education has been facing for the last decades.

1.3. Purpose of the Study

The purpose of this study is to understand dimensions of engineering disciplinary culture. To study culture at the disciplinary level Hofstede's constructs to measure dimensions of culture were tested. Hofstede (1980) developed four constructs to measure dimensions of culture holistically by understanding people values about different aspects that define their culture at the national level. However, those constructs can provide information to understand how students interpret them to make inferences to describe the culture at the disciplinary level. The constructs are: *power distance* (from small to large) that can help explain how students understand authority in the classroom, and faculty-students relationship, *individualism* (versus collectivism) that can help explain how students understand collaboration with other students and interactions with other disciplines, *uncertainty avoidance* (from weak to strong) that provide insights on students' comfort levels with structure and clear rules (or vice versa), and *masculinity* (versus femininity) that can provide information regarding students' perceptions of gender equality in engineering.

Specifically, I started by using Hofstede's original four dimensions of national business cultures (power distance, uncertainty avoidance, individualism, masculinity) (Hofstede, 1980) to see if his model could explain disciplinary cultural differences in engineering majors. Hofstede's model was selected because it has been used to characterize culture from how people in the corporate world value. The model can provide information regarding how students feel, think, and act regarding their major, rather than focusing on how knowledge is built and transferred in the major (i.e. focus on the cultural perspective, not the epistemological perspective of the discipline). Although his model was developed to measure culture at the national level, it provided with information on how students define

the dimensions that helped start developing a way to understand disciplinary culture from a new perspective when complemented with other theoretical frameworks that focused more on academic disciplinary differences (i.e. Nulty, 1996, and Bradbeer 1999).

There are three aims of this study, which are addressed and presented in three separate manuscripts. The first aim (Manuscript 1) identifies how Hofstede's theory of dimensions of national culture maps to academic disciplines. For this aim, I used a valid and reliable survey adapted from Hofstede's theory and collected quantitative data in different majors to determine if his model of measuring dimensions was adaptable to different engineering majors.

The second aim (Manuscript 2) of this study is to review the extensive available literature regarding the critiques of Hofstede's model and its implementation in different settings. The literature review included literature since Hofstede's model was published the first time in 1980. The main critiques of his theory are categorized. In addition, the successful application of his model in different settings is presented. The goal is to understand the limitations of the framework used in this study and to understand how to adequately use it to inform the third manuscript to explore engineering culture in academic settings.

The third aim (Manuscript 3) of this study is to explore students' perceptions of disciplinary engineering culture and how those perceptions compare to other disciplines, using a qualitative interview protocol. The interview protocol was informed by the dimensions developed by Hofstede and the theoretical frameworks of disciplinary culture from the perspectives of teaching and learning developed by Bradbeer (1999) and Nulty and Barrett (1996). The qualitative approach provided deep rich information on how undergraduate engineering students perceive their disciplinary engineering culture.

1.4. Research questions

I propose to use Hofstede's constructs of dimensions of national culture to better understand how students perceive their disciplinary engineering culture. To achieve this goal, this mixed methods study will aim to answer the following overarching research question: In what ways can Hofstede's cultural dimensions' framework contribute to better understanding disciplinary engineering culture?

In addition, I will use different methods to answer the following specific research questions in my project:

RQ1: Can Hofstede's model of dimensions of national cultures be used to explain disciplinary cultural differences?

RQ2: What are the primary categories of critiques of Hofstede's survey instrument?

RQ3: How can these limitations be minimized to make Hofstede's model appropriate for adaptation to an academic setting?

RQ4: How do undergraduate engineering students perceive their disciplinary engineering culture in comparison to students in marketing, and industrial design?

1.5. Significance of the Research

This research provides contributions to engineering education in practice, research, and policy. By investigating how undergraduate students perceive their disciplinary culture, I hope to provide valuable information to better understand the engineering discipline in order to better inform students, faculty, and administrators on how to improve engineering schools.

For practice, this research provides information about aspects of teaching and learning from the students cultural perspective that engineering instructors can use to better understand how students perceive their classrooms, and start thinking about what changes

can be done in their pedagogies. In addition, the information can provide support to freshmen engineering students when making decisions on their engineering major. If they understand how students perceive the culture of the discipline, they will be likely to make a more informed decision in what they want during their time in college.

This study also provides contributions to engineering education research. It provides researchers with information to advance the understanding of a complex construct like culture, by the use of different theoretical frameworks from education, and business and sociology. In addition, the findings provide information for researchers on understanding engineering disciplinary culture in terms of the cultural characteristics we describe in this study.

In addition, this study has implications for policy and administration. Findings can inform administrators in order to make decisions on students' requirements to be admitted or transferred into engineering programs, and selection criteria when engineering faculty are being hired and trained. Similarly, findings can help administrators evaluate different aspects of the engineering program like whether prerequisites and co-requisites in engineering curriculum are making sense for the engineering majors, and whether current admission and transfer criteria are the best methods to admit engineering students that will succeed. Results can also inform on the focus of K-12 outreach programs since it will be easier to find students that will have what the major values.

1.6. Scope of the Study

The purpose of this research study is to understand how undergraduate engineering students perceive their disciplinary engineering culture and to see if Hofstede's constructs can map to academic majors. Therefore, the research design is a mixed method approach that allowed me to test Hofstede's instrument in academic settings quantitatively through

surveys, and explore in more detail qualitatively how to better use Hofstede's theory, and through this mixed design explore in depth how undergraduate engineering students perceive their disciplinary culture. My study will be exploratory; the aim is to obtain a better understanding of the engineering disciplinary culture, and to provide a useful theoretical approach to be used later to inform how to improve engineering classrooms. As such, results from this study will not directly improve any of the problems described previously in engineering education, but will serve as an initial point of information in the development of those recommendations for improvement.

Quantitative data collection for this study was conducted over a period of two years using a valid and reliable version of Hofstede's instrument. Qualitative data was collected over two semesters. This research study is focused on undergraduate engineering students enrolled in a large research university. A more thorough discussion of the research design is discussed in the following section.

1.7. Overview of the Methods

The methodology design for this study is mixed methods. According to Creswell and Clark (2011), mixed methods designs sequentially combine and integrate two forms of data (quantitative and qualitative) in a single study, and give priority to one form of data depending on the research problem. In this study, the first step was to use a quantitative approach to collect data from a version of Hofstede's survey developed by Sharma (2010) in order to measure how students score regarding Hofstede's constructs. In Chapter 3, I explain in detail why Sharma's version of the survey was selected, and how the author validated his instrument.

Results from the quantitative study led to the second step of conducting a systematic review of the literature regarding Hofstede's main critiques and how other

authors have successfully implemented his model in different context.

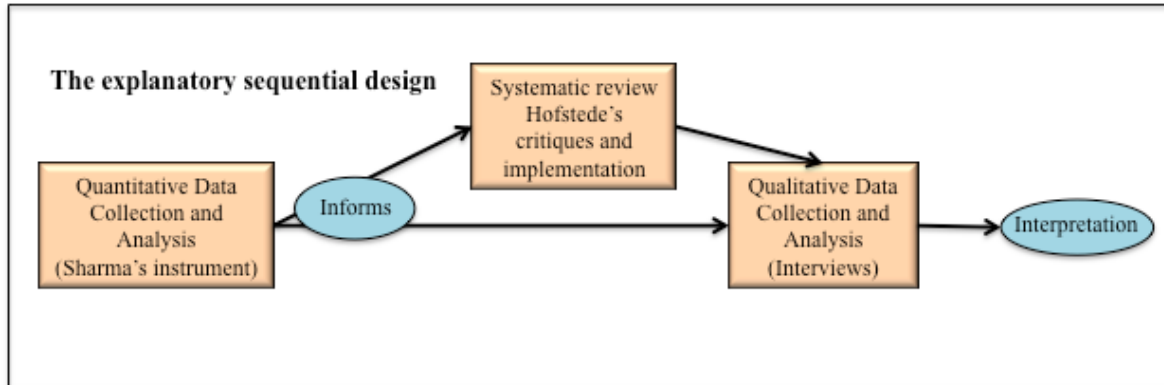


Figure 1. Explanatory Sequential Mixed Method Design (adapted from Creswell and Clark, 2011)

The third step is to collect qualitative data with semi-structured interviews with undergraduate engineering students.

More specifically, the design of the overall study is an explanatory sequential design (Figure 1) that begins with the collection and analysis of quantitative data, followed by subsequent collection and analysis of qualitative data, with the qualitative analysis being informed by preliminary results from the initial quantitative phase (Creswell & Clark, 2011). In addition, each phase of my dissertation will be explained in detail in three manuscripts.

In my study, I used Hofstede's constructs to collect quantitative data that provided insights to the dimensions of disciplinary culture of undergraduate engineering students. Since culture is a complex construct, initial findings also helped to inform the interview protocol for understanding more in depth some of the students' responses regarding the disciplinary cultures; being able to compare and contrast both sets of data helped to obtain a better understanding of the phenomenon. Based on the quantitative data also, I completed a systematic review of the literature that helped me identify the value and limitations to

Hofstede's constructs, as well as the application of his model in different contexts. The systematic review will allow me to overcome the initial problems encountered with the preliminary quantitative data analysis. Finally, I conducted interviews to further explore how students understand their engineering disciplinary culture and how it compares with students in different majors.

The method design of my research was selected based on the purpose and the research questions, and it is visually represented in Figure 1. Table 1 shows how each manuscript will aim to answer different research questions, and how each research method will help me answer them. The quantitative phase is the collection and analysis of data from a version of Hofstede's survey and addressed research question 1. The systematic review is the second manuscript and helped me transition from the preliminary results in the quantitative phase and to shape the qualitative phase, this phase addressed research questions 2 and 3. The qualitative phase is the collection and analysis of data from interviews with undergraduate engineering students, and students from marketing, and industrial design, to address research question 4. The interview protocol was developed based on the preliminary results of the quantitative data and taking into consideration the data collected in the systematic review. Table 1 presents a summary of the manuscripts, the methods to answer each research question, as well as the sample and data collection strategies for each question. More detailed information regarding the manuscripts is presented in the next sections.

1.7.1 Validity and reliability

Bryman (2006) suggests that mixing quantitative and qualitative research, and demonstrating that the combination is more than the sum of the parts, is one of the key issues of mixed methods research.

Table 1

Method, sample, and data collection and analysis techniques for research questions.

Research question	Data collection - Method	Analysis	Expected outcome
RQ1: Can Hofstede's model of dimensions of national cultures be used to explain disciplinary cultural differences?	Quantitative: Use of Hofstede's survey in undergraduate students	Descriptive and inferential statistics using SPSS reliability analysis, factor analysis.	<u>Manuscript 1:</u> Description of Hofstede's dimensions used to measure engineering culture
RQ2: What are the primary categories of critiques of Hofstede's survey instrument? RQ3: How can these limitations be minimized to make Hofstede's model appropriate for adaptation to an academic setting?	Qualitative: Systematic review of the literature	Systematic review of the literature	<u>Manuscript 2:</u> Value and limitations of Hofstede's dimensions of culture: A systematic review of the literature
RQ4: How do undergraduate engineering students perceive their disciplinary engineering culture in comparison to marketing and industrial design?	Qualitative: Semi-structured interview	Thematic analysis using MaxQDA Multiple raters Emergent data	<u>Manuscript 3:</u> Understanding students' perceptions of engineering disciplinary culture

The author defines several criteria to justify the need to combine quantitative and qualitative research. In my study, I will use both approaches for most of the reasons presented in the criteria (Bryman, 2006):

1. Different research questions: In order to justify mixed methods research it is necessary that the project has different types of research questions that need to be answered by different methods (i.e. quantitative, or qualitative). I will use mixed methods research because of the different nature of my research questions. In this study, RQ1 requires a quantitative approach to test how Hofstede's constructs map to disciplinary culture at the academic level. RQ2 requires a qualitative approach in order to identify the relevant authors that have critiqued and used Hofstede's theory

to find ways to overcome issues regarding his model. RQ3 also requires a qualitative approach since the question is about the value of using Hofstede's constructs in academic settings. RQ4 also should be answered with a qualitative approach because it is about how engineering students provide their deep and rich perceptions regarding engineering disciplinary culture.

2. Explanation: It is important to determine whether one method can be used to help explain findings generated by the other. Initial quantitative data collection provides information on how students score regarding Hofstede's constructs, providing a general idea of how engineering disciplinary culture is described. However, the limited sample size, and the lack of statistical significance motivated a systematic review of the literature to understand the main critiques to Hofstede's model. Both the quantitative study and the literature review informed the qualitative design.
3. Unexpected results: The use of quantitative and qualitative methods combined should enhance the understanding of surprising results. In the pilot quantitative study (Murzi et al., 2014) we obtained information regarding how students score on Hofstede's constructs in different disciplines; however, every engineering major reported similar patterns of dimensions of disciplinary cultures. For example, we argue that industrial engineering students have more uncertainty avoidance than electrical engineering students. Using qualitative interviews helped us go deeper on how students understand perceive the dimensions –like uncertainty avoidance- in their discipline.
4. Enhancement or building upon quantitative/qualitative findings: The use of a method should improve the arguments made about a different method. The quantitative information on how students define the patterns of dimensions of

disciplinary cultures is limited to descriptive scores regarding Hofstede's constructs. This information is complemented by qualitative data where students were able to provide rich information about how they perceive and experience the phenomenon (i.e. engineering disciplinary culture).

5. Triangulation or greater validity: Triangulation is the convergence, corroboration, and correspondence of the results from different methods (Bryman, 2006). To understand the engineering disciplinary culture, I used both quantitative and qualitative data to allow triangulation of the findings that provide a better understanding of the how undergraduate engineering students understand their discipline in terms of cultural dimensions. Using different methods helped me corroborate the findings of my study from different sources improving the validity of my study.

The term "validity" has been addressed in quantitative and qualitative research extensively; however, in using mixed methods, determining validity is more complex. Several authors incorrectly address validity of mixed methods studies by addressing separately the validity of the quantitative and qualitative portions of the study (Creswell & Clark, 2011; Dellinger & Leech, 2007). Thus, it is very important to address the validity of the mixed methods as a whole in the study, in addition to using quantitative strategies of validation in the quantitative section, and qualitative strategies of validation in the qualitative section. In my study several authors (Dellinger & Leech, 2007; Onwuegbuzie & Johnson, 2006; Onwuegbuzie, Johnson, & Collins, 2011) will guide my data collection and analysis to ensure validity of my mixed methods design. The validity process is described in Table 2:

Table 2

Validity process for the study design.

Step	Definition	Implementation strategy
Sample integration	Refers to the integration of the findings of a large sample (quantitative), to the findings of a smaller subset of the same population (qualitative) (Johnson, Onwuegbuzie, & Turner, 2007; Onwuegbuzie et al., 2011).	I will use sample integration by using some of the students that responded to the quantitative study as participants in the qualitative study. In addition, quantitative responses from different majors will be contrasted with interview responses from participants of the same major.
Inside-outside	Refers to the need to be clear on the differences between the insider's view (students) and the observer's views (researcher) and accurately present the differences for purposes such as description and explanation. (Johnson et al., 2007; Onwuegbuzie et al., 2011).	In manuscript one, I will describe the reasons why I proposed the hypothesis of the study. In addition, in the qualitative manuscript, I will develop an entire section to elaborate regarding my own experiences and how those can affect my biases regarding the study. In addition, I will make sure to not make any assumptions about the students' responses.
Weakness minimization	Consists of actively looking for the weaknesses of one research approach, and compensate those weaknesses with strengths from the other research approach (Johnson et al., 2007; Onwuegbuzie et al., 2011).	Each manuscript will have a very detailed limitations section that will describe in depth all the possible weakness of each portion of the study. In addition, each manuscript was developed in order to overcome the limitations of the previous study (i.e. manuscript 2 addresses limitations of manuscript 1, manuscript 3 addresses limitations of manuscripts 1 and 2).
Multiple validities	Refers to the use of quantitative, qualitative, and mixed validity types, yielding high quality meta-inferences (Dellinger & Leech, 2007; Johnson et al., 2007).	Each manuscript will have a section regarding the validity of the study. In the section, detailed information will be provided in addition to the use of a recognized criteria to ensure validity.
Inferential consistency	Refers to whether the study design, measurement, and analysis are consistent given what is known from past research, and theory (Dellinger & Leech, 2007).	I expect this study to be consistent with previous replications and application of Hofstede's construct. Also, manuscript 2 is an extensive systematic review of the literature that provides information regarding Hofstede's main critiques, and the value of using his theory based on previous studies that were successful.

In addition, more information about validity and reliability is explained in detail in the following sections when I describe each manuscript.

1.8. Limitations

There are several limitations to consider in the development of this study. First, using a model developed for measuring national culture might not be adaptable to measuring disciplinary culture. Hofstede's model was developed to measure dimensions of national culture. Therefore, its application provides information on the culture at the national level rather than at the disciplinary level. Nevertheless, the grant that supported this study was approved to explore the application of Hofstede's dimensions at the disciplinary level. The study increased the validity of Hofstede's model on measuring national culture and it helped inform the development of the interview protocol in combination with other theoretical frameworks that provided information to understand disciplinary cultural differences in engineering.

Another limitation of this study is participant bias. Participants for the interview will be students who have voluntarily decided to collaborate. It is possible that students who choose to participate in a study about disciplinary culture can have unique perspectives about engineering culture than students who choose otherwise.

Finally, there is a limitation regarding the researcher bias. I have been involved in engineering disciplinary culture for twenty years as an undergraduate student, graduate student, faculty member, and researcher in engineering schools. In addition, I have been involved in research about academic culture in my hometown university in Venezuela for more than 8 years. My personal experience provides me with some beliefs about engineering disciplinary culture, and perceptions about how students understand their dimensions of culture that I need to be aware of in order to avoid my personal beliefs to influence my data analysis. In order to limit the impact of my researcher bias, it is

necessary for me to take several approaches towards maintaining the study's reliability and trustworthiness.

2. Chapter 2. Overview of the Literature

In this chapter, I present an overview of the literature regarding how to understand disciplinary engineering culture. First, I provide information on academic culture, and the importance of understanding it. Then, I explain the reasons why I decided to study disciplinary cultures. In addition, a thorough description of Hofstede's theory of dimensions of national culture is provided, including a description of its main critiques. Finally, I explain why Hofstede's model can be implemented to understand disciplinary engineering culture.

2.1. Academic Culture

All entities have social structures that shape the beliefs of their members and provide guidance on how they behave and act (Becher, 1994; Clark, 1980, 1997).

According to Clark (1980), these social structures are known as the "entity culture." Meaning that the social structure has a culture that belongs to the structure and its shared by its members. Academic systems are considered social structures that have shared beliefs; therefore, the system has a culture. Identifying and understanding the culture of the system is very complex (Becher & Trowler, 2001; Clark, 1980).

Academic culture according to Clark (1997) refers to the agreement on core values and common frameworks shared by members of academic institutions. However, the author suggests that the concept is more ideal than realistic because different disciplines promote different values inside institutions. Nevertheless, Becher (1981) suggests that the set of disciplines in academic settings possess a common culture: "their ways of construing the world and the people who live in it are sufficiently similar for them to be able to understand, more or less, each other's culture and even, when necessary, to communicate

with members of other tribes (disciplines)” (p.152). One of the ways that academic culture is shared by faculty members despite their discipline is with the concept of “academic freedom” (Clark, 1997). In addition, academic culture has strong meaning for academics despite their disciplines in the sense that the academic system has been able to bring together academic excellence, scientific preeminence, and universal access in order to pursue knowledge adjusting to student and society needs (Clark, 1997). Academic culture provides guidance on what is accepted by students and faculty members on how to behave, learn, interact, teach, and collaborate in the academic discipline (Peterson & Spencer, 1990).

Austin (1990) explains that the academic culture provides overarching integrative values that link faculty members and students beyond their disciplines and institutions. The author affirms that the purpose of higher education is to “pursue, discover, produce, and disseminate knowledge, truth, and understanding” (p.62); therefore, students during their time at school and faculty members during their academic career value, understand, and act according to the purposes of higher education. However, Graubard (1997) affirms that academic culture is about the recognition, integration, and collaboration of different disciplines (Graubard, 1997).

Despite academic culture having an impact on students and faculty members in the way they understand their role in academic communities, specific academic disciplines are considered the best organizational structure to facilitate the pursuit of knowledge (Austin, 1990; Graubard, 1997). Disciplinary cultures provide a set of values, behaviors, characteristics, and social rules that are accepted by the discipline and shared by all their members and that go beyond the ones in academic culture. The differences between disciplines will have more power than the similarities that academic culture provides to

every member of the system. The academic culture provides general rules on how to achieve the purpose of higher education, but disciplinary cultures provide the rules on how to become a member of a specific discipline. Disciplinary cultures are more important for developing the identity of the students in terms of how and what they need to learn, and how they need to behave to success in their professional careers. They also provide the rules for how faculty members should conduct their teaching, research, communicational, mentoring, and role modeling processes.

2.2. Why disciplinary cultures?

From a cultural perspective, Ylijoki (2000) suggests that universities do not form a homogeneous whole, but an heterogeneous entity with different “small worlds” (p.339). The author explains that disciplines vary cognitively and socially. Thus, it is possible to assume that disciplines have their own traditions, cognitive biases, norms, values, forms of interactions, pedagogical strategies, and lifestyles. Students who belong to a particular discipline will share similar disciplinary cultures, and they will share the same differences with other disciplines (Ylijoki, 2000).

Austin (1990) explains that in the academic profession, the primary unit of “membership and identification” is the discipline (p.63). Understanding of disciplinary cultures can provide with information about the acceptable norms of conduct and acceptable behaviors in a respective field in terms of the symbols, traditions, and appropriate professional activities, which shape how the discipline is experienced and understood. Disciplinary differences impact the lives of faculty members, students, and professionals in every field (Austin, 1990), hence the understanding of disciplinary cultures becomes necessary in higher education. Research conducted by Becher (1994) identified different systems of classifying disciplines based mostly on teaching and learning

processes, but these systems stemmed from the perspectives of faculty members and administrators. Since the culture of a discipline is the central source for identity development at a faculty and student level (Austin, 1990; Becher, 1994) its comprehension must include the students' perceptions.

According to Becher (1994) understanding those differences between disciplines is key to the higher education system, and he suggests that disciplines are the life-blood of higher education. Disciplines provide the main organizing base for academic institutions; therefore there is a need to understand each discipline in terms of its culture.

2.2.1. Disciplinary cultures and differences

As mentioned before, academic disciplines are “the primary units of membership and identification within the academic profession” (Austin, 1990, p.63). Clark (1997) asserts that understanding disciplinary cultures is more important than understanding demographics (i.e. race, religion, and gender) in determining academic-centered thoughts and behaviors of faculty members and students. Furthermore, bodies of knowledge (disciplines) will determine the behaviors (culture) of individuals and academic departments (Becher, 1994; Becher & Trowler, 2001; Clark, 1997).

Greenhalgh (1997) defines disciplinary culture understanding as the process of studying academic disciplines in terms of the control of its knowledge, organization, production, and the social practices that maintain such control. Disciplinary cultures create a lot of differences between faculty members and students that go beyond the similarities of the academic culture. Variations across disciplines focus on the way students learn, interact with peers and faculty, solve problems, communicate, participate in and outside the classroom, and understand their academic discipline. In addition, variations across disciplines can be found in the way faculty members teach, conduct research, communicate,

interact with peers, interact with students, mentor, and behave in their academic discipline (Greenhalgh, 1997).

Several authors have studied disciplinary cultures. In most of the literature, the authors focused on the classification of the disciplines in term of their differences. In the following sections I will present the most relevant research regarding disciplinary differences from different perspectives and approaches, then I will explain why I believe Hofstede's theory is valuable to help with the understand of disciplinary cultures in the engineering discipline. It is important to note that with the complexity involved in measuring and understanding culture, I am not proposing to only use Hofstede's framework as the only way to understand disciplinary cultures in engineering majors, rather I will complement the information that Hofstede's framework can provide with other theories regarding how disciplines can be classified and analyzed.

Lodahl and Gordon (1972) established disciplinary differences based on paradigm development in each discipline. The main differences in disciplinary culture using paradigm development as the basis, is on the use of a shared vocabulary for discussing the content of the field, and the way scientific findings have been discovered and implemented in the field. Although this classification provides valuable information for research and communicational processes, there is a lack of information on how students understand their disciplinary culture, the way they interact with others, and the teaching and learning processes of their discipline.

Similarly, Biglan (1973) proposed a classification of disciplines along three different dimensions: (i) hard-soft, (ii) pure-applied, and (iii) life-nonlife. Hard-soft refers to the existence (or not) of a consensus over a single paradigm or body of knowledge. Hard disciplines have a better consensus about content and method because they shared a unique

paradigm. Soft disciplines lack a guiding paradigm, therefore, content and method in these disciplines tend to be idiosyncratic (Biglan, 1973). Pure-applied differentiates disciplines based on their focus on practical application (applied), or abstract theorization (pure). Finally, life-nonlife refers to the focus on living systems rather than non-living entities. The three dimensions interact in terms of how the discipline is perceived to form 8 possible sub-categories. Biglan (1973) focuses his work on the social structure of the disciplines but only from the perspective of the cognitive processes of faculty members in different areas. His categories can help understand how faculty members differentiate in the content and the methods in the discipline. One problem with this approach is the lack of information regarding how students perceive their learning processes and their cultural discipline.

Probably one of the most recognized authors regarding disciplinary cultures is Becher (1981). The author proposed some categories to divide disciplines by separating social (cultural) and cognitive (epistemological) dimensions. The cognitive dimension includes a spectrum from soft to hard, and a continuum from pure to applied sciences. Based on the classification according to the author, there are four possible groups for disciplines: hard-pure, soft-pure, hard-applied, and soft-applied. Hard fields focus on the development of theoretical structure (Becher, 1994), while soft fields have unclear boundaries (unspecific) regarding theoretical structure. The author based his theory on data collected regarding research norms and practices of the disciplines, as well as, the main issues regarding graduate education on the fields. Also, in this model engineering is studied as a whole with no consideration to differences between engineering majors.

Bradbeer (1999) presented a summarized outline on disciplinary differences based on Kolb's model of learning processes. He suggests that four different dimensions can interact to develop learning: active experimentation, concrete experience, reflections and

observations, and abstract conceptualization. In this study, the emphasis for the basis of differentiation between disciplinary cultures is on learning styles. Similarly, Nulty and Barrett (1996) used the same framework to define disciplinary differences but included a dimension called “transitional field.” Disciplines in this category are changing over time and shifting their epistemological beliefs. Hofstede’s theory can be compared to these models to see how his dimensions map to the different learning styles proposed by Kolb in order to have more detailed information regarding the disciplinary cultures to make better curriculum and administrative decisions.

Hofer (2000) proposed disciplinary differences on an epistemological basis. She analyzed how students perceive their disciplines in terms of how they make meaning and the assumptions they hold about knowledge and knowing, which can influence comprehension and learning. Hofer (2000) defines two areas to classify disciplines based on epistemological differences: “the nature of knowledge (what one believes knowledge is) and the nature or process of knowing (how one comes to know)” (p. 380). Each category has two dimensions to differentiate the academic discipline. Regarding the nature of knowledge, the dimensions are certainty of knowledge (i.e. the degree to which knowledge is perceived as fixed) and the simplicity of knowledge (i.e. knowledge perceived as a continuum or accumulation of facts) (Hofer, 2000). On the nature of knowing, the first dimension is the source of knowledge (i.e. where knowledge originates) and justification for knowing (i.e. how individuals evaluate their knowledge claims) (Hofer, 2000). This study provides valuable information about how students perceive epistemological differences in their disciplines. However, the study only analyzed psychology against science as the two main disciplines. Engineering was not analyzed. Furthermore,

information was collected on how students think the knowledge is created in their disciplines, but they were not asked about their learning processes.

As explained before, all these studies present different approaches to categorize disciplinary differences from pedagogical and epistemological approaches. However, the only perspective analyzed in most of them is the faculty members' perspective not the students' perceptions. Furthermore, the frameworks were designed based on how the faculty members described their thinking, research, and teaching processes based on classroom settings and experiences, or research practices, all factors that have evolved considerably over time. In addition, all these studies generalize engineering as a whole and don't consider differences between engineering majors.

As mentioned before, there are several studies that have done research in disciplinary differences that could be used to study engineering disciplinary culture. However, for my study, I decided to use Hofstede, Bradbeer, and Nulty models to help me gather information from a different perspective. I examined culture not only from the students' academic perspective but also in terms of their perspectives beyond the classroom settings.

The reason to select Hofstede was primarily because of the value that the model has to provide a cultural perspective based on the values of people's work. Hofstede's model will provide a better understanding of how engineering students perceive the culture of their discipline in terms of what they value regarding work, and how they feel, think, and act in their field. Hofstede's theory provides a vision beyond the cultural discipline from the academic perspective of the faculty, and can focus on the values and perceptions of the students. In addition, Bradbeer and Nulty were selected because the frameworks provide clear information on practical application of how to understand disciplinary differences.

2.3. Hofstede's theory of dimensions of national culture

Hofstede introduced his conceptualization of culture after developing his theory of cultural dimensions in the mid-1960s. In his initial study, he analyzed the cultural differences among nations by surveying employees at IBM in more than 50 countries regarding their personal values. Hofstede's framework was first published in 1980 in his book "Cultural Consequences: The dimensions approach." Hofstede (1980) initial definition of culture is developed based on his observations of the desired and desirable values of IBM's employees around the world. He described culture as a "collective programming of the mind." He explained that cultural patterns are rooted in value systems of major groups of individuals and became stabilized over long periods of time, as the acceptable way of thinking. His definition of culture has evolved over time; in more recent books Hofstede, Hofstede, and Minkov (2010a) define culture as patterns of thinking, feeling, and acting that every human being carries. He has constructed a metaphor of culture as the *software of the mind*, -based on his initial definition that culture is a collective programming of the mind- characterizing culture as a mental program that is developed by social interactions and experiences collected since the early life of an individual: "the programming starts within the family; it continues within the neighborhood, at school, in youth groups, at the workplace, and in the living community" (p. 6). More recently, Minkov and Hofstede (2013) define culture as a "system of shared meanings that may be unique to a particular society or a group of societies" (p.4).

Hofstede (1980) original analysis yielded four dimensions of culture based on the problems that were inherent to all societies: (a) social inequality, including the relationship with authority, (b) the relationship between the individual and the group, (c) ways of dealing with uncertainty and ambiguity, which turned out to be related to the control of

aggression and the expression of emotions, and (d) concepts of masculinity and femininity: the social and emotional implications of having been born as a boy or a girl. Based on these issues Hofstede (1980) labeled his dimensions of culture as *power distance* (from small to large), *individualism* (versus collectivism), *uncertainty avoidance* (from weak to strong), and *masculinity* (versus femininity).

Hofstede et al. (2010a) expanded to six dimensions in later studies. The two newer dimensions are not included in this study because they appear to have less bearing on disciplinary culture: *long-term/ short-term orientation* address virtues stemming from teachings of Confucianism such as “thrift” or “respect for tradition,” and *indulgence/restraint* represents a continuum of how satisfied and happy individuals in a certain nation are with their lives. While these dimensions may be useful delineators for national cultures, the values addressed are less relevant to disciplinary contexts because they refer primarily to Culture at a more general level. For example, long/short term orientation focuses on the role that family, marriage, and other long-term relationships play in the value system of a person, and it would be complex to evaluate how those aspects relate to disciplinary culture. In addition, indulgence/restraint is about how people perceive gratification and happiness; therefore the concept shouldn’t be related to disciplinary culture.

Hence, in this study the focus is on the original four dimensions:

- Power Distance addresses the degree to the extent to which the “less powerful members of institutions and organizations within a country expect and accept that power is distributed unequally” (Hofstede et al., 2010; p.61). Notably, this dimension addresses inequity as defined and endorsed from below (i.e. the followers rather than the leaders) (Hofstede, 1993; Hofstede et al., 2010a).

Exploring disciplines via this dimension can address patterns of student and faculty relationships, preferences for autonomy, communication patterns, and preferred problem types.

- Uncertainty Avoidance/Acceptance addresses the degree to which members of a culture can operate comfortably with uncertainty. According to Hofstede et al. (2010a) in cultures with high uncertainty avoidance, unstructured situations (novel, unknown, surprising, etc.) are perceived as intimidating; these cultures seek to minimize such situations via both legal controls (e.g. laws, rules, security measures), and religious philosophies that rest on absolute truth. Cultures that accept uncertainty, in contrast, tolerate diverse opinions, have fewer rules, and adopt more relativist philosophies. Exploring disciplines via this dimension can address students' abilities and willingness to collaborate, especially in interdisciplinary teams of unfamiliar territory, as well as their openness to creative formulations of problem solutions.
- Individualism/Collectivism addresses the relationship between individuals and the larger group. In an individualistic culture, individuals are loosely connected: everyone is expected to operate independently and people do not strongly identify with a group norm (Hofstede et al., 2010a). In collectivist cultures, people are tightly connected and consolidated into cohesive in-groups with strong emphasis on group norms and unity (Hofstede et al., 2010a). Exploring disciplines via this dimension can address participation of underrepresented populations in engineering, where collectivist interventions, such as living and learning communities, has proven to be effective social and academic support networks.

- Masculinity/Femininity refers to the continuum representing how emotional roles are distributed across genders, with assertive roles aligned with the masculine pole of the continuum and caring roles aligned with the feminine pole. Notably, in Hofstede's studies, women show less variation by culture than men; i.e. men are more assertive and competitive in masculine cultures, while women exhibit similar levels of caring in both masculine and feminine cultures. Masculine cultures thus experience a greater gap between men's and women's roles (Hofstede et al., 2010a). Exploring disciplines via this dimension may address women's participation in the masculinized culture of engineering that moves beyond the metaphors of "pipeline" and "chilly climate."

In the following section, I will expand on the value of using Hofstede's theory to explore disciplinary culture in engineering majors, as well as the limitations of his framework.

2.4. Value and limitations of Hofstede's theory

Culture is a major factor that influences how systems work and evolve over time (Becher & Trowler, 2001; Hofstede, Hofstede, & Minkov, 2010b; Peterson & Spencer, 1990). The importance of understanding disciplinary cultures according to Austin (1990) is that culture is an interpretive framework that can provide information at different levels to better understand and improve common practices in academic disciplines. Hofstede's model of cultural dimensions can be tested to see if it can provide more information for the understanding of aspects of disciplinary culture that are beyond teaching and learning processes. Considering the limitations of the previous studies on disciplinary differences from epistemological and pedagogical perspectives, it is necessary to complement those

valid perspectives with a new one -that can be provided by Hofstede- specific to the engineering discipline.

Peterson and Spencer (1990) suggest there is an existing need to measure culture in terms of dimensions. Since culture is such a complex construct, the use of specific dimensions is necessary to be able to capture behavioral patterns, values, beliefs, and ideologies, that it is important not only make disciplines unique but also to highlight the distinctiveness across disciplines (Becher & Trowler, 2001; Clark, 1997; Peterson & Spencer, 1990). The identification of the specific scores of Hofstede's dimensions in engineering majors can help understand the discipline's unique meaning (Peterson & Spencer, 1990), and to be able to contrast it with other engineering majors and other disciplines.

There is value in testing Hofstede's theory of dimensions of national culture in academic settings. Hofstede's model uses dimensions of culture that have been validated in a variety of contexts and scenarios. According to Fang (2003), Geert Hofstede is one of the most cited names in the Social Sciences Citation Index (SSCI). In the cross-cultural management field, his work on cultural dimensions is considered to be the most influential theory explaining cultural differences in management styles. Nevertheless, Hofstede's model has been criticized over the years. In the following sections, I explain the main critiques that Hofstede's have received on the literature, as well as how other researchers have been able to successfully implement Hofstede's theory of dimensions of national culture.

2.5. Critiques of Hofstede's Research

In the following sections, I present the main critiques found in the literature to Hofstede's theory of cultural dimensions. The critiques are divided into two categories: one

related to how scholars critique Hofstede's on conceptual grounds, and the second one regarding critiques to his instrument on methodological grounds. In addition, I explain how some scholars have not critiqued Hofstede's theory itself, but rather incorrect applications of his survey. Finally, I conclude with an overview of successful applications.

2.5.1. Conceptual critiques.

Several authors have critiqued Hofstede's theory based on conceptual grounds. In this section I will summarize the conceptual critiques.

2.5.1.1. Defining Culture. Culture itself is notoriously difficult to define (McCurdy, Spradley, & Shandy, 2004; Miroshnik, 2002; Williams, 1983, 1985) with definitions ranging from Edward Burnett Tylor's (1871) assertion that culture is a complex whole (including knowledge, beliefs, morals, law, habits, and capabilities) that is acquired by every person belonging to a society; to definitions of culture as the reflection on the way a certain group of people perceive, appraise, and experience the world (Klein, 2004). Some authors measure culture as learned behaviors, others as abstractions from behaviors, and still others measure culture as the relation between selected objects and their meanings to people. Culture exists only in the mind according to some, so it can only be measured with self-reporting; according to others culture can be measured by the observation of behaviors and events in the external world (Kluckhohn & Kelly, 1944; Kroeber & Kluckhohn, 1952; Segall, Campbell, & Herskovits, 1966). Hofstede (1980, 1993); Hofstede et al. (2010a) defines culture as the way people perceive their values in terms of the desirable and the desired (i.e. beliefs on how the world should be versus what people desire for themselves). The desirable refers to what is right and wrong, acceptable or not by society (Hofstede et al., 2010a). On the other hand, the desired is about individuals, and the things that they want for themselves (Hofstede et al., 2010a). While society establishes norms, policies, and

rules about what is perceived as good or positive in the desirable, the desired values can be subjective. This subjectivity in the spectrum of values and definitions points to one of the problems of identifying and measuring culture. Jahoda (1984) affirms that culture is the “most elusive term in the generally rather fluid vocabulary of the social sciences” (p.40). Similarly, Minkov and Hofstede (2013) refers to the complexity of studying culture: “Culture, just like intelligence, seems to be one of those wonderfully easy topics on which nearly everybody feels qualified to express a competent view” (p.2). Across definitions, culture is considered a complex phenomenon. It is something intangible that sometimes cannot be captured even by the individuals that participate in it (Linton, 1945; Segall et al., 1966). Furthermore, while it is possible to see individuals and their interactions, no one can observe culture directly (Goldschmidt, Beals, Goldschmidt, & Hoijer, 1970; Kluckhohn & Kelly, 1944). Therefore, trying to analyze, compare, and understand different cultures becomes a challenging task.

2.5.1.2. Critiques to Hofstede’s concept of culture. Some researchers base their critiques of Hofstede’s theory in aspects related to different approaches to how he defines and measures culture.

One critique is regarding how Hofstede’s equates culture to nations. Baskerville (2003) evaluated applications of Hofstede’s *Culture’s Consequences* in the field of accounting research, examining Hofstede’s development of ideas about culture and its quantification, and critiquing the theoretical bases for Hofstede’s cultural measurements. Baskerville’s review identified problems including: (i) the assumption of equating nation with culture, (ii) the difficulties of, and limitations on, a quantification of culture represented by cultural dimensions and matrices; and (iii) the status of the observer outside the culture. The author argues that “culture is not divided into component systems, or

different values in a quantitative style; instead, it is viewed as an integrated pattern of symbols and meanings” (p. 2).

To support these critiques, Baskerville (2003) conducted a citation analysis to determine the disciplines that are using Hofstede’s theory, and found that psychology and management-related disciplines cite Hofstede’s work more than sociology and anthropology. Baskerville, who is an accounting and finance scholar, claims that the expertise on culture resides in the fields of anthropology and sociology, and thus Hofstede’s approach may lead to methodological problems.

For example, Baskerville (2003) argues that countries should not be treated as unit of analysis. From a sociology and anthropologist perspective, he argues, in a particular nation there may be different cultures present. Hofstede, on the other hand, based his theory on the assumption that differences in nations can be treated similar to differences in cultures. Additionally, Hofstede uses the concepts of culture and society interchangeably; in ethnographic studies the anthropologist may describe one or many societies within a nation state (Baskerville, 2003; Brewer & Venaik, 2012).

Similarly, Fang (2010) argues that in the twenty-first century it is not possible to frame people’s behaviors into cultural dimensions. Globalization has given rise to a paradoxical movement of cultures and management practices in which modern people have multicultural identities and multicultural minds beyond their national cultures (Everett, Stening, & Longton, 1982; Fang, 2010; Pascale & Maguire, 1980).

McSweeney (2002b) challenged the assumptions that underlie Hofstede’s cultural dimensions by questioning the way the dimensions were developed. The author’s first critique was regarding the assumption that IBM organizational culture does not vary across

nations, leading him to determine that the differences in the responses are because of the differences in national cultures.

Another related critique was regarding how Hofstede links workplace behaviors to larger social cultures. McSweeney (2002b) states that the assumption that people's behavior in the workplace is representative of the other aspects of someone's life is wrong; rather, people sometimes behave differently in the workplace because of social pressures or organizational culture. The last assumption considered incorrect is that employees of one company are the reflection of one nation.

In addition, the author considers that Hofstede's cultural dimensions are not situational because they lack contextual considerations. The author explains that there is no systematic causation regarding the notion of national cultures for several reasons: (i) Hofstede does not consider the influence of sub-cultures enough, (ii) he relies on a single explanatory variable to explain cultural causation, leaving out the possible explanations that non-national cultures and the non-cultural could contribute to the behaviors, and (iii) Hofstede assumes that people belonging to a national culture are homogeneous.

Another concern is how Hofstede treats culture as being static and linear. Ford, Connelly, and Meister (2003) state that Hofstede's work assumes that culture is static over time, and since the cultural dimensions fall along national boundaries there is an implicit assumption that national culture is homogenous. In reality in every national culture, subcultures exist and can explain several of the differences between Hofstede's cultural dimensions. The author argues that in some cases people belonging to different and opposed countries according to Hofstede's dimensions can be positioned in similar scales for belonging to similar sub-cultures.

In addition, Hampden-Turner and Trompenaars (1997) argue that cultural categories

cannot be linear and exclusive (i.e. a person can be individualistic and collectivistic at the same time under different circumstances), rather the context influences the specific cultural position of an individual at a given time, allowing people to be in different poles of the same scale or even to stay in between. The authors consider culture to be circular and variant, instead of linear and exclusive, as Hofstede affirms.

According to Fang (2012), the perception of cultural learning as extending “longitudinally from one’s own ancestors within one’s own cultural group” (p.26) is not adequate anymore. In addition, there is a concern that culture evolves over time (Fernandez, Carlson, Stepina, & Nicholson, 1997; Søndergaard, 1994; Wu, 2006) and Hofstede’s perceptions of cultural dimensions should change as well. Several authors propose that the dimensions developed in Hofstede's theory correspond only to the period of time in which the study was conducted (1960s) and those dimensions have been incorrectly treated as if they do not change over time [Warner, 1981; Lowe, 1981; Baumgartel and Hill, 1982; cited by Wallace, Hunt, and Richards (1999)].

Finally, in a study developed by Hampden-Turner and Trompenaars (1997), the authors critique the fact that Hofstede expresses culture in mathematical language, and in linear and exclusive categories. They claim that because culture has a dynamic and adaptive nature it is not possible to correctly quantify it based on numeric dimensions and matrices (Hampden-Turner & Trompenaars, 1997). Instead, culture is a qualitative variable rather than quantitative, and culture has meanings that depend upon the context and external factors (Baskerville, 2003). Single elements of the context cannot dictate meaning to explain the whole phenomenon (Baskerville, 2003; Hampden-Turner & Trompenaars, 1997).

2.5.2. Methodological critiques.

Hofstede's model has been subject to several critiques based on methodological grounds, including lack of internal consistency, replicable dimensions, validity, and generalizability, and finally problematic wording of the dimensions themselves.

2.5.2.1. Internal consistency. Several authors have affirmed that Hofstede's model lacks internal consistency when using the dimensions to measure cultural differences.

In order to examine the empirical validity of Hofstede's cultural framework, J. Blodgett, G., A. Bakir, and G. Rose, M. (2008) conducted an exploratory study in which the results indicated that the cultural framework, when applied at the individual unit of analysis, is lacking reliability. A sample of 157 students and faculty members was asked to review Hofstede's original 32-item cultural instrument and to indicate which dimension (power distance, individualism/collectivism, uncertainty avoidance, masculinity/femininity) each particular item was intended to address. Cronbach alpha was computed for each item, the results were for individualism/collectivism 0.666, for masculinity/femininity 0.651, for uncertainty avoidance 0.351, and for power distance 0.301. The authors consider that those results do not demonstrate the internal consistency that was expected. According to Santos (1999), in 1978 Nunnally established 0.7 as the minimum acceptable Cronbach alpha to demonstrate internal consistency.

Similarly, Spector, Cooper, and Sparks (2001) affirm that Hofstede's research does not provide information on internal consistency or reliability of his instrument. The authors conducted a study on 23 of the 40 countries that Hofstede's theory was based on using his original instrument. Participants in the sample were administrative employees mostly on managerial positions. Out of 115 Cronbach alpha calculated, only 13 achieved the 0.7 coefficient that is considered the minimum acceptable alpha. The authors concluded that

the unacceptable low internal consistency is an indicator that Hofstede's instrument lack internal consistency.

2.5.2.2. Replications of the dimensions. Other researchers have tried to replicate his framework and have found that some dimensions don't hold up. Fischer, Vauclair, Fontaine, and Schwartz (2010) critique the stability of the country-level dimensions in Hofstede's model. The authors argue that the model had several different steps in the analysis and thus generated a significant amount of lengthy sequences of probabilities, which needed further cross-validation. They based this argument in their failure to replicate results for two of the factors. These failures to recover the dimensions in independent samples provide a need for stability of the country-level dimensions. The authors suggested subsequent research based on testing the similarity of value structures across levels directly.

Similarly, Smith, Dugan, and Trompenaars (1996) were not able to replicate all of Hofstede's dimensions when using his theory. Using different sources of information in the study, they tried to replicate the cultural differences, and the findings were that the masculinity-femininity and the individualism-collectivism dimensions could not be replicated. Chanchani and Theivanathampillai (2002) evaluated Hofstede's dimensions in comparison to other cultural typologies, realizing that the Hofstede's model was lacking transcendence in the level of analysis and did not have application for another research project.

In addition, Smith et al. (1996) were not able to replicate all of Hofstede's dimensions when using his theory. Using different sources of information in the study, they tried to replicate the cultural differences and the findings were that the masculinity-femininity and the individualism-collectivism dimensions could not be replicated. Chanchani and Theivanathampillai (2002) evaluated Hofstede's dimensions in comparison

to other cultural typologies, realizing that the Hofstede's model was lacking transcendence in the level of analysis and did not have application for another researches.

2.5.2.3. *Validity.* Another criticism of Hofstede's theory focuses on the validity of his methodology. Validity in quantitative research refers to the process of accumulating evidence to determine whether a researcher can obtain meaningful information to make useful inferences from data collected, which means that the test is measuring what the is intended to measure (J. W. Creswell, 2013; Goodwin & Leech, 2003; Moskal, Leydens, & Pavelich, 2002). Moskal et al. (2002) suggest that validity is obtained when there is evidence that supports interpretations and the appropriateness of how those interpretations are used. Validity is considered to be the most fundamental consideration in the development of evaluation tests (Goodwin & Leech, 2003). There are several types of critiques regarding validity that will be discussed in this section: first face validity, then construct validity, and last external validity.

In order to determine the face validity of Hofstede's instrument, J. Blodgett, A. Bakir, and G. Rose (2008) asked the participants of their study (157 students and faculty members) to map Hofstede's survey questions to the dimensions of culture that he developed. On average only 41.3% of the time respondents matched the question to the correct dimension. According to the authors, this demonstrated that Hofstede's instrument is lacking face validity.

Generalizability of his findings may be affected from the fact that survey respondents are from a single large multinational corporation (IBM). Fernandez et al. (1997) argue that the information collected in his study may be biased by the fact that the sample belonged to a single company. This affirmation is supported by Søndergaard (1994) on his analysis of researchers that have cited Hofstede. He found that several researchers

citing this issue as a main critique to the model. People working in a company tend to develop an organizational culture that sometimes may affect their national cultural beliefs. It is possible that employees at IBM around the world had developed some organizational values that affected their responses (Smircich, 1983). Generalizability of the findings is also affected by gender and occupation; in Hofstede's study mostly male respondents working in marketing and servicing were on the sample (Banai, 1982; Robinson, 1983).

Finally, Triandis (1982) call for the use of triangulation when applying Hofstede's study. The author considers the use of a single method of data collection for measurement as too limited, especially when analyzing complex concepts like cultural dimensions. The author suggests using a multi-method research design in order to obtain reliable information from different sources that can explain the results. This affirmation was accepted and shared by Hofstede himself.

2.5.2.4. *Type of instrument used to measure culture.* Søndergaard (1994) affirms based on his research that the use of attitude surveys does not constitute a valid basis for understanding culture. The author is concerned about Hofstede's instrument being an attitude survey that is flawed to measure culture. Similar questions have been raised by other scholars about the validity of inferring values from attitude surveys alone (Smucker, 1982; Schooler, 1983).

2.5.2.5. *Wording of the dimensions.* Chiang (2005) raises concerns regarding Hofstede's labeling of the dimensions. For example, the term masculinity–femininity has generated some criticism because it may have a sexist tone that is not adequate in some cultures, and power-distance can be considered, inappropriately, as an indicator of inequality. Adler (1997), cited by Chiang (2005), suggested that it would be necessary to change the label of the power-distance dimension to career success/quality of life in order

to avoid additional criticism.

2.5.3. Incorrect application of Hofstede's constructs.

Finally, some authors have critiqued not Hofstede's theory but its applications as researchers have attempted to apply a theory of national cultures to the individual level. Brewer and Venaik (2012) affirm that the national culture dimensions' characteristics, scales and scores are often used in research and teaching as if they apply to individuals, when they do not. They highlighted the misapplication of Hofstede's national culture dimensions at the individual level of analysis in both research and teaching. This phenomenon was defined by Piantadosi, Byar, and Green (1988) as the *ecological fallacy*, i.e. to wrongly assume that relationships observed for groups will hold for individuals. Items in Hofstede instrument were highly correlated at the national level, but at the individual level correlation was very low or inexistent and sometimes contradictory (Grenness, 2012).

2.6. Examples of successful application of Hofstede's theory

In this section, I present some of the practical applications of Hofstede's model and how some researchers have successfully addressed its main critiques.

Regarding reliability critiques, several authors have been able to use Hofstede's instrument and probe internal consistency in its use. Ang, Van Dyne, and Begley (2003) studied the differences in work perceptions, attitudes, and behaviors of foreign compared to local employees in companies from different industries in China and Singapore. They measured uncertainty avoidance in 466 employees based on Hofstede instrument with five items developed specifically for their study and they were able to prove reliability in Hofstede's instrument with a general Cronbach's alpha of 0.77. Similarly, Ardichvili and Kuchinke (2002) used Hofstede's instrument to understand leadership styles and cultural

values among managers and subordinates in independent companies in 6 countries, and the reliability tests proved internal consistency in the instrument.

According to Hofstede et al. (2010b), six major replications of his study have been conducted in several countries. Hoppe (1998) tested the construct validity of Hofstede's dimensions using his survey. He obtained data from 1500 respondents in 19 countries and was able to use statistical analyses to demonstrate validity and reliability of Hofstede's model using a different sample (i.e. managerial, professional, political, and academic elites). The strongest dimension he was able to replicate was masculinity. Shane, Venkataraman, and MacMillan (1995) were also able to replicate 3 of the 4 dimensions in a study conducted to identify the relationship between national culture and national preferences for innovation championing strategies. They had a sample of 1228 individuals in 30 countries. The authors confirmed the reliability of Hofstede's scales with Cronbach alpha, and validity was established by (i) consulting the instrument with experts in cultural psychology, engineering, and innovation, (ii) using statistical procedures like factor analysis and correlations, and (iii) comparing results of the research with previous results of Hofstede's original work.

In another study conducted by Chiang (2005), it was possible to determine the influence of culture on reward preferences in employees. The author used Hofstede's model for understanding how cultural differences can shape the types of rewards employees desire the most. However, the author explains that contextual factors may influence these decisions as well.

Similarly, Merritt (2000) incorporated Hofstede's survey questions to the Flight Management Attitudes Questionnaire (FMAQ), and collected data for four years using a sample of 9,417 pilots in 26 airlines in 19 countries. The author replicated Hofstede's study

and was able to demonstrate the reliability and validity of his survey. Merritt (2000) first did a pilot testing of the questions, followed by a correlational analysis between the pilots' responses and Hofstede's original country scores for each dimension. A second analysis was conducted by correlating all items in the database—including Hofstede's items with the new items written for the pilot survey—with Hofstede's index scores. Finally, a cluster analysis was done with the data obtained in the study that generated clusters that were similar to what was expected according to Hofstede's dimensions, demonstrating validity of Hofstede's model.

De Mooij (2010) also replicated 3 of the 4 dimensions proposed by Hofstede. The author used Hofstede's model to explain cultural differences in consumer behaviors. Hofstede's instrument was used in combination with a marketing questionnaire, obtaining results in which three dimensions correlated significantly with the country scores of Hofstede's initial study. The author also demonstrated reliability with an internal consistency analysis. De Mooij (2010) affirms, after conducting a literature review on Hofstede, that his dimensions are increasingly used as a valid conceptual framework to classify and explain the influence of culture on several different research topics outside their original setting.

Another replication of Hofstede's theory was conducted by Mouritzen and Svava (2002). The authors explained the cultural context of leadership in politicians. They were able to replicate 3 of Hofstede's 4 dimensions and correlated the form of government with the Hofstede's index. They also conducted a cluster analysis that allows them to demonstrate validity of Hofstede's model in a political context. Van Nimwegen (2002) also replicated Hofstede's study in banking settings and was able to demonstrate validity using a cluster analysis and correlations of his data with Hofstede's original results.

Similarly, Ardichvili and Kuchinke (2002) used Hofstede's instrument to understand leadership styles and cultural values among managers and subordinates in independent companies in 6 countries. In this study the reliability tests proved internal consistency in the instrument.

Yoo, Donthu, and Lenartowicz (2011) developed a scale based on Hofstede's model to measure the dimensions of national culture (individualism, power distance, uncertainty avoidance, and masculinity) at the individual level. The author modified Hofstede's original instrument and improved it using the support of several experts that were familiar with Hofstede's theory. The improved instrument was piloted and probed with several responses obtaining internal consistency in all the four dimensions with ranges of Cronbach alpha from 0.71 to 0.96. In addition to demonstrating reliability the authors conducted an exploratory and a confirmatory factor analysis with data from three separate samples, obtaining the expected results that established construct validity. In addition, validation was established by applying the instrument in three different countries on different populations always obtaining similar results when doing statistical procedures like factor analysis.

Furthermore, several studies (At-Twajiri & Al-Muhaiza, 1996; Cheung & Chan, 2010; Elenkov & Manev, 2005; Entarkin & Chung, 2001; Giacobbe-Miller, Miller, Zhang, & Victorov, 2003; Heuer, Cummings, & Hutabarat, 1999; Huettinger, 2008; Li, Chick, Zinn, Absher, & Graefe, 2007; Liu et al., 2009; Naumov & Puffer, 2000; Prašnikar, Pahor, & Vidmar Svetlik, 2008; Rarick & Nickerson, 2008; Reisinger & Crotts, 2010; Soares, Farhangmehr, & Shoham, 2007; Tang & Koveos, 2008; Twati, 2008; Yoon, 2009) have successfully used Hofstede's theory and replicated his model to study cultural differences, making an argument for the validity and reliability of the model.

Finally, in his book *Culture's consequences*, Hofstede and Hofstede (2001) describe over 200 external comparative studies that have supported his dimensions, corroborating reliability and validity of his theory.

In this study, we are testing Hofstede's model, that has been proven to be valid and reliable to measure national culture and see if it maps onto academic disciplines.

Hofstede (2002) himself replied to most of his criticism in a reply written to McSweeney (2002a). First, he stated that most of the concerns that McSweeney pointed out were addressed in a posterior edition of *Culture's Consequences* (2001). One of his criticisms was that surveys are not an optimal way of researching cultures; Hofstede acknowledges that affirmation. He suggests using several methods to obtain trustworthy information regarding culture. His argument is that surveys are a valid method to do research in sociological sciences and supported by other methods can provide the required results to understand a complex phenomenon like culture. Regarding the concern that nations should not be the unit of analysis for studying cultures, he also agrees with the statement but explains that researchers do not have many options considering that boundaries of cultures cannot easily be determined. He affirms: "they are (nations) usually the only kind of units available for comparison and better than nothing" (p.2).

Another addressed concern is regarding the obsolete data from the IBM study. Hofstede (2002) explained that the dimensions that he developed have their roots in information that is centuries-old. He also pointed out that only the data that remained stable across two subsequent surveys were used for the development of his theory. He affirms that over the years his instruments have been subjected to different tests of validity and reliability, demonstrating both. He argued that cultures do not change rapidly over time. Regarding complex phenomenon that are difficult to understand and observe – like culture

– data that is twenty and thirty years old can be still considered to provide accurate findings, as has been confirmed by numerous replication studies (At-Twajri & Al-Muhaiza, 1996; Cheung & Chan, 2010; Elenkov & Manev, 2005; Entekin & Chung, 2001; Giacobbe-Miller et al., 2003; Heuer et al., 1999; Huettinger, 2008; Li et al., 2007; Liu et al., 2009; Naumov & Puffer, 2000; Prašnikar et al., 2008; Rarick & Nickerson, 2008; Reisinger & Crotts, 2010; Soares et al., 2007; Tang & Koveos, 2008; Twati, 2008; Yoon, 2009).

A final concern addressed by Hofstede himself was about the development, quality, and quantity of the cultural dimensions. He states that dimensions are independent in concept and statistical analysis. He affirms that the current dimensions should be validated with external measures of correlations. He is continuously working in the development of new categories and evaluating the validity of the current ones.

Although Hofstede's study was conducted in organizational contexts and only considered results as a Nation, it is possible to identify that the Hofstede's model of culture has been constantly used in cross-cultural research and have been able to successfully interpret a large variety of research findings. Based on these studies it is possible to argue that Hofstede's methodology can be tested to see if his framework is useful to study cultural differences in sub-cultures, like academic disciplines. The model can provide with an understanding of the engineering disciplinary culture that focuses on what students value regarding the discipline that shape how they understand the workforce. It provides with a business perspective that engineering education hasn't explored in depth. So far, disciplinary cultural perspectives in engineering education have focused on the epistemological perspective of knowledge in the discipline, with Hofstede's framework we expand the value of understanding the disciplinary culture from the students' perceptions of what they value, how they feel, think, and act in the discipline.

Another value of using Hofstede's theory to understand disciplinary cultures in engineering majors is regarding the information that the dimensions can provide. The four dimensions (individualism, uncertainty avoidance, power distance, and masculinity) are constructs that respond to social issues shared by almost every person belonging to any type of culture (Hofstede & Hofstede, 2001; Hofstede et al., 2010b), these constructs based on this literature review can be useful to understand disciplinary engineering culture quantitatively but also can inform the qualitative data collection, allowing students to have a deep reflection on their experiences with their discipline regarding every dimension. Following I will elaborate more on each dimension, and its value to understanding engineering disciplinary culture.

2.6.1. Individualism

According to Hofstede (2011), cultures can be described in terms of individualism or its opposite, collectivism. Individualism refers to the degree which people in a system are integrated with other members of the system. In individualistic cultures people do not develop strong ties with others, they only look after their own interests (Hofstede, 2011). On the other hand, in collective cultures people develop strong, cohesive, and loyal relationships with other members of the group. This dimension is particularly important to understand disciplinary culture in engineering majors, because there is a demand for engineers to be able to work collaboratively in teams, and to solve problems with people that think different (Rugarcia et al., 2000; Shuman et al., 2005; Tryggvason & Apelian, 2006), therefore by understanding how engineering students perceive their individualism it will be possible to develop pedagogical strategies (like team projects or grades) that promote collaboration, inclusion, and participation in collective spaces (like living learning communities).

2.6.2. Uncertainty avoidance

Uncertainty avoidance refers to a culture's tolerance for ambiguity (Hofstede, 2011). It indicates to what extent members of the culture feel comfortable or uncomfortable with the lack of structure in different situations. Cultures with high uncertainty avoidance will try to establish strict behavioral codes, laws, and rules to avoid ambiguity and uncertainty (Hofstede, 2011). This dimension can provide valuable information on how engineering students feel about thinking outside the box, changing rules, and working with other disciplines that are unknown to them. In addition, it will provide with information on how well curricula is structured in terms of clear rules.

2.6.3. Power distance

Hofstede (2011) defines power distance as the extent to which a given system supports unequal power distribution. This dimension addresses inequality defined from the perspective of the members of the system in lower power positions. Understanding power distance can provide information regarding student and faculty member interactions and relationships, preferences for autonomy, communication patterns, and the role of the follower (student) and the leader (faculty) in the discipline.

2.6.4. Masculinity

According to Hofstede (2011) masculinity refers to the distribution of values between genders. Masculine cultures are associated with assertiveness and competition, while feminine cultures are associated with caring and modesty. This discipline is also very important for the understanding of disciplinary cultures in engineering majors because it may provide information that helps change the masculine perception of the engineering field. It can also provide information to improve inclusion and diversity, and to make engineering schools more welcoming.

Hofstede's model also allows understanding of disciplinary cultures in engineering students based on their individual perceptions about their values and behaviors beyond the classroom. Hofstede et al. (2010b) affirm: "values, more than practices, are the stable element in culture, comparative research on culture starts from the measurement of values" (p. 28). Most of the models discussed previously describe differences in disciplinary cultures based on accepted practices in the discipline (epistemological perspective of how knowledge is built and transferred), rather than on the values that the members of the academic units shared (cultural perspective on how students perceive values, thinking, and feeling in the discipline). The questions around Hofstede's constructs make them think about how they are, and what they value.

In engineering majors for example, different academic departments with very similar curricula and course structures can perform very differently because of the varying perceptions that members of the department may hold regarding their disciplinary culture (Tierney, 1988). Hofstede's dimensions can provide information on how students can be similar or different in the way they behave in their disciplines in terms of culture with constructs that are not directly related to academic settings (i.e. individualism, power distance, uncertainty avoidance, and masculinity).

Similarly, Hofstede's theory can provide information regarding how engineering majors can function better not only with other engineering majors, but also with other disciplines. Hofstede's theory can be valuable in overcoming the main issues proposed by Bradbeer (1999) as barriers to interdisciplinarity: (i) differences in disciplinary epistemology, (ii) differences in disciplinary discourses, (iii) differences in disciplinary traditions of teaching and learning, and (iv) differences in students' preferred learning approaches and styles. By understanding Hofstede's dimensions of disciplinary culture in

engineering majors, it will be possible to inform faculty members with information to make decisions regarding teaching strategies to accommodate different learning styles, and also to provide information to students to help them become self-aware learners.

I plan to address the limitations of Hofstede's theory by developing a mixed methods study, and incorporating additional frameworks when analyzing my data. In addition to Hofstede's survey results, I developed an interview protocol based on this literature review and information provided by initial quantitative data collection. In addition, I used the frameworks provided by Becher and Trowler (2001); Bradbeer (1999) and Nulty and Barrett (1996) to inform the interview protocol for qualitative data collection. The mixed methods approach, in conjunction with having additional perspectives to explore disciplinary cultures will provide me with a bigger picture about engineering disciplinary culture from the perspectives of students.

3. Chapter 3. Manuscript 1: Applying Hofstede's dimensions to engineering culture

3.1. Abstract

Background: Hofstede's theory of dimensions of national culture is one of the most cited and implemented frameworks in sociology, business, and management for understanding cultural differences in different contexts. We are using his framework to study disciplinary differences in engineering majors.

Purpose: The purpose of this study is to understand how Hofstede's dimensions of cultural differences can map to engineering disciplinary culture to explain cultural differences in engineering majors.

Scope/Method: A version of Hofstede's instrument was used to collect data quantitatively in 3,385 undergraduate students. Data were analyzed in three different stages, a pilot study, an engineering students' study, and a first year students' study. Factor analysis, analysis of variance, descriptive and inferential statistics analysis were conducted.

Conclusions: The study confirmed Sharma's version of Hofstede's instrument validity and reliability. We were able to find some differences between engineering majors regarding Hofstede's dimensions, however, the differences are minimal. It was not possible to map Hofstede's framework to explain cultural disciplinary differences in engineering majors.

3.2. Introduction

Since the establishment of ABET's EC2000 in 1997, the engineering education community has been striving to determine the factors, pedagogies, content, and strategies that can help undergraduate engineering students develop the skills they require to become innovative professional engineers. Some of the most important skills are considered to be

teamwork, creativity, problem solving, and adaptive expertise (Jesiek et al., 2014; Redish & Smith, 2008; Terenzini et al., 2001). Faculty members in engineering often struggle to provide such skills without sacrificing discipline-specific problem-solving competencies (Clough, 2004). At the same time, engineering programs continue to struggle with attracting and retaining members of underrepresented populations—populations whose diversity could greatly contribute to innovation. Interestingly, the inability to promote these skills without sacrificing the technical skills, and the lack of diversity in engineering, are often attributed to cultural traits of the field, which is often characterized as masculine, individualistic, structured, and function-oriented. To address these issues, in this manuscript, I will study patterns of cultural traits in undergraduate engineering students to identify if culture can provide a better understanding of the issues described. Specifically, I plan to apply Hofstede (1993) constructs of dimensions of national cultures (power distance, uncertainty avoidance, individualism, masculinity) to academic disciplines to explain how engineering education is perceived by the students. In this paper, I describe the process of using Hofstede's theory—very well known in sociology and business—and adapt it to academic settings. The motivation for using Hofstede's dimensions to understand engineering culture is associated with the lack of collaboration (related to individualism and power distance), creativity (related to uncertainty avoidance and power distance) and interdisciplinary fluency (related to all the dimensions) in undergraduate engineering students. In this study I answer the following research questions:

RQ1: Can Hofstede's model of dimensions of national cultures be used to explain disciplinary cultural differences?

The purpose of this study is to understand how Hofstede's dimensions can be used to explain cultural differences in academic disciplines. To study culture at the disciplinary

level I will use Hofstede's constructs as originally developed in 1980. The constructs were designed to measure dimensions of culture holistically by understanding people's values about different aspects that define their culture at the national level. The constructs are: *power distance* (from small to large), which can help explain how students understand authority in the classroom, and faculty-student relationships, *individualism* (versus collectivism), which can help explain how students understand collaboration with other students and interactions with other disciplines, *uncertainty avoidance* (from weak to strong), which can provide insights on students' comfort levels with structure and clear rules (or vice versa), and *masculinity* (versus femininity), which can provide information regarding students' perceptions of gender equality in engineering.

Hofstede (1980) developed his constructs by analyzing data available from a questionnaire in IBM that was designed to survey employees about their values. The questions looked to capture values, but Hofstede (1980) states that it also was able to capture what is "desirable vs. desired" (p.43). Hofstede (1980) argued that surveys that focus on the interpretation of the values and neglect the desirable and the desired could lead to paradoxical results. Based on this, the author used this quantitative data to be able to study and establish cultural differences between countries based on the perceptions of people's values considering what they thought was desirable for them as individuals, and desired as the general norm.

This research project is designed to use a version of Hofstede's instrument and see if the model can explain disciplinary cultural differences. However, it is anticipated that results will provide information on culture at the national level rather than the disciplinary level. Nevertheless, results are expected to provide valuable information regarding engineering disciplinary culture and students' values that can explain how they act in the

discipline. The information presented in this project is part of a larger NSF Grant in which we are conducting a longitudinal study to explore how the perceptions of disciplinary culture in students in different disciplines (engineering and non-engineering) evolve over time.

3.3. Theoretical background

Hofstede introduced his conceptualization of dimensions of national culture, after analyzing the cultural differences among nations by surveying 88,000 respondents from 66 countries in 50 occupations employees at IBM. Hofstede's framework was first published in 1980 in his book "Cultural Consequences: The dimensions approach." Hofstede et al. (2010a) define culture as patterns of thinking, feeling, and acting that every human being carries. More recently, Minkov and Hofstede (2013) defined culture as a "system of shared meanings that may be unique to a particular society or a group of societies" (p.4). Hofstede (1980) labeled his dimensions of culture as *power distance*: the extent to which the "less powerful members of institutions and organizations within a country expect and accept that power is distributed unequally" (Hofstede et al., 2010b; p.61); *individualism*: the relationship between individuals and the larger group (Hofstede et al., 2010b); *uncertainty avoidance*: the degree to which members of a culture can operate comfortably with uncertainty (Hofstede et al., 2010b); and *masculinity*: the continuum representing how emotional roles are distributed across genders, with assertive roles aligned with the masculine pole of the continuum and caring roles aligned with the feminine pole (Hofstede et al., 2010a).

Hofstede's model of cultural dimensions can be a practical framework to understand and interpret aspects of disciplinary culture that are beyond teaching and learning processes, and understand them from constructs used successfully to measure cultural

differences at the national level with data from employees of a corporation. This corporate perspective can provide additional information in engineering education to better understand how students perceive their disciplinary culture beyond their classroom practices and how they obtain knowledge, rather this model provides with how they act, feel, behave, and what they value.

Peterson and Spencer (1990) suggest there is an existing need to measure culture in terms of dimensions. Since culture is such a complex construct, the use of specific dimensions is necessary to be able to capture behavioral patterns, values, beliefs, and ideologies that, in the case of academic fields, make disciplines unique but also to highlight the similarities across disciplines (Becher & Trowler, 2001; Clark, 1997; Peterson & Spencer, 1990). Hofstede's model has been proven, in a variety of contexts, to be reliable (Ang et al., 2003; Ardichvili & Kuchinke, 2002; Hoppe, 1998; Merritt, 2000; Yoo et al., 2011) and valid in identifying cultural differences (Chiang, 2005; De Mooij, 2010; Hoppe, 1998; Merritt, 2000; Mouritzen & Svara, 2002; Shane et al., 1995). Therefore, Hofstede's constructs describe some cultural characteristics of undergraduate engineering students, and see if we can learn more about the disciplines.

Since Hofstede's study was conducted in organizational contexts and only considered results at national levels, we hypothesize that students in different engineering majors will have similar results in their scores, because the majority of the students will have the similar national culture (i.e. United States citizens), however we are interested in understanding if engineering students in different engineering majors have characteristics that differentiate them from the national group, or if we can identify some values that are specific to the discipline. Hofstede's four dimensions (individualism, uncertainty avoidance, power distance, and masculinity) are constructs that respond to social issues

shared by almost every person belonging to any type of culture (Hofstede & Hofstede, 2001; Hofstede et al., 2010b), so this information obtained from these constructs can help us understand how well Hofstede's theory to define culture is able to explain some of the characteristics of the disciplinary engineering culture. The identification of the specific scores of Hofstede's dimensions in engineering majors is critical to understanding the engineering discipline's unique meaning (Peterson & Spencer, 1990), and to be able to contrast both within engineering majors and across other disciplines.

Hofstede's constructs can provide guidance to narrow down some of the complex features of culture and being able to understand it at the national level. However, in this study we plan to use the scores to focus on aspects of culture that can relate to academic disciplines rather than society. For example, scores on individualism will be used to inform how students' perceptions of collaboration are.

3.4. Methods

In this section we will explain our quantitative research design. We provide information on the instrument we used for the study, the procedure of collecting the data, the process of data analysis, and the limitations of our study. Initially, we provide information about our pilot study to be able to determine which version of the survey to use and its validity and reliability.

3.4.1. Pilot Study

In order to answer the research question, data were collected quantitatively using an improved version of Hofstede's original survey (Appendix A). The first step in this research was to do a pilot study of the selected version of the instrument to confirm its validity and reliability in academic settings.

3.4.1.1. Instrument. A literature review was conducted, and we were able to identify more than 20 adapted versions of Hofstede's surveys. However, we decided to research in more detail three versions that thoroughly explained their processes of affirming validity and reliability. After discussions with our team of researchers we selected the version of Hofstede's instrument developed by Sharma (2010) for several reasons. The author used some of Hofstede's initial items and improved some of the questions, then went through a rigorous process of scale development and validation. First, the author did an extensive literature review covering more than 200 papers published from 1980 to 2009, supplemented with 50 interviews with participants from different cultures. With that process, it was possible to improve the items that represented each dimension (Sharma, 2010). Next, the author established face and content validity using the expertise of a panel of judges. Sharma (2010) used four independent academic judges with experience in cultural studies, and who had different cultural backgrounds (ethnic Chinese, Asian Indian, African American, and Caucasian European). The judges rated the preliminary items developed and the ratings were compared, leaving only the items that were highly rated by all the judges. Then, the author followed established procedures for scale development. He conducted first a scale refinement and purification study, followed by a scale validation study. He was able to establish convergent, discriminant, nomological, and predictive validity (Sharma, 2010). With data collected from more than 2,000 individuals Sharma (2010) conducted a confirmatory factor analysis and was able to establish the construct validity of the instrument. Finally, the author conducted a third study of replication and generalization. In this final study, the author confirmed reliability of the instrument with Cronbach's alpha, and a high load of the constructs with a factor analysis. Also, he conducted correlations between the scales obtaining support for what it was predicted.

Lastly, Sharma (2010) compared the scale with other two scales using a regression model, being able to explain greater variance in a couple of dependent variables with the new scale. Therefore, it was possible to suggest that generalization of the findings from the first two studies were valid.

Sharma (2010) proposed 8 constructs in his survey to measure Hofstede's dimensions of culture. Individualism (INDV) is measured by the negative correlation between independence (IND) and interdependence (INT). Power distance (PDI) is measured by the positive correlation between power (POW) and social inequality (IEQ). Uncertainty avoidance (UAI) is measured by the positive correlation between risk avoidance (RSK) and ambiguity intolerance (AMB). Finally, Masculinity (MAS) is measured with another construct that Sharma (2010) labeled gender equality (GEQ).

3.4.1.2. Data collection procedures. The version of the survey was administered online using Qualtrics. Data collection procedures were approved by IRB. An email inviting to participate in the study was sent by the Assessment office. Two reminders were sent. Students participating approved an electronically consent form on the first page of the survey (Appendix B). Students took no more than 25 minutes to fill out the 38 questions survey. Data about GPA, demographics, major, and semester were collected. In addition, students could provide their email if they wanted to participate in a follow-up study regarding their responses.

3.4.1.3. Sample. We piloted the survey for our study during the Fall 2013 semester, and 1261 undergraduate students at a Research University responded. The sample included students from 55 different majors, however 79.93% of the responses came from majors in engineering. There is no information regarding the response rate because the office of assessment didn't provide the exact number of students that received the survey link. There

was 87% of completion rate meaning that out of 1,449 students that started the survey, only 1261 students finished it. Before conducting any analysis missing data were imputed following Dempster, Laird, and Rubin (1977) procedures of the Expectation Maximization algorithm to reduce the number of lost cases, and avoid biases. Missing values were confirmed to be random with a little's missing completely at random (MCAR) test (chi-square = 261.120, DF = 974, and sig. = 0.980).

3.4.1.4. Validity and reliability. Using the Statistical Package for the Social Sciences (SPSS), an exploratory factor analysis was conducted to demonstrate validity of Sharma (2010) instrument. Factor analysis is a statistical procedure that examines interrelationships among items in order to identify clusters of items that highly correlate with each other (Krathwohl, 1993). From the exploratory factor analysis it was possible to identify 8 factors (Table 3) using principal axing factoring as the extraction method. In order to determine how many factors to retain, we used Kaiser's criterion. According to Yong and Pearce (2013), Kaiser's criterion suggests retaining all factors that are above the eigenvalue of 1, therefore we selected 8 factors. Since Sharma (2010) version of Hofstede's instrument used 8 constructs to demonstrate Hofstede's four dimensions, the results were indicating what we were expecting regarding the factor analysis.

In addition, in Table 4 it is possible to see that after using a Promax rotation method that is commonly used when researchers assume that there is some correlation expected among the factors (Yong & Pearce, 2013). We decided to use Promax because culture is a social construct so we anticipate some correlation among the factors, since behaviors and values cannot be totally partitioned into individual units that work independently from one another. The pattern matrix shows that the factors loading together are the same constructs developed by Sharma (2010), increasing the validity of his instrument. After tests

demonstrated reliability and construct validity of the Sharma (2010) instrument, data were collected to understand Hofstede's dimensions scores in undergraduate students. However, the sample size for majors outside engineering was very small and not representative. Therefore, the analysis and discussion of the results of this study will be focused only on engineering majors.

Table 3.

Exploratory Factor Analysis – Total variance explained

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings ^a
	Total	% Var.	Cum. %	Total	% Var.	Cum. %	Total
1	5.078	15.869	15.869	4.606	14.394	14.394	3.044
2	3.848	12.024	27.893	3.381	10.567	24.961	3.497
3	2.734	8.545	36.438	2.235	6.983	31.944	3.140
4	2.202	6.881	43.319	1.685	5.265	37.209	2.363
5	1.842	5.756	49.076	1.316	4.111	41.320	3.129
6	1.517	4.740	53.816	1.046	3.267	44.587	1.864
7	1.265	3.952	57.768	.817	2.554	47.141	1.938
8	1.173	3.666	61.434	.662	2.068	49.210	2.846
9	.999	3.122	64.556				
10	.922	2.880	67.437				
11	.789	2.466	69.902				
12	.772	2.414	72.316				
13	.752	2.350	74.665				
14	.645	2.014	76.680				
15	.609	1.904	78.584				
16	.600	1.876	80.460				
17	.566	1.769	82.229				
18	.523	1.634	83.863				
19	.515	1.609	85.472				
20	.487	1.521	86.993				
21	.471	1.471	88.464				
22	.432	1.349	89.813				
23	.420	1.312	91.125				
24	.402	1.257	92.382				
25	.376	1.174	93.556				
26	.344	1.075	94.631				
27	.339	1.059	95.690				
28	.331	1.034	96.723				
29	.304	.951	97.674				
30	.290	.908	98.582				
31	.236	.738	99.320				
32	.218	.680	100.000				

Extraction Method: Principal Axis Factoring.

Table 4.

Exploratory Factor Analysis – Pattern Matrix after rotation

	Factor*							
	1	2	3	4	5	6	7	8
Gender equality - GEQ3	.859							
Gender equality - GEQ4	.826							
Gender equality - GEQ1	.707							
Gender equality - GEQ2	.676							
Risk aversion - RSK3		.877						
Risk aversion - RSK1		.732						
Risk aversion - RSK2		.694						
Risk aversion - RSK4		.559						
Power - POW1			.820					
Power - POW4			.739					
Power - POW2			.690					
Power - POW3			.660					
Interdependence - INT3				.735				
Interdependence - INT4				.671				
Interdependence - INT2				.615				
Interdependence - INT1				.611				
Ambiguity intolerance - AMB1					.922			
Ambiguity intolerance - AMB2					.815			
Ambiguity intolerance - AMB4					.378			
Ambiguity intolerance - AMB3					.350			
Independence - IND1						.775		
Independence - IND3						.741		
Independence - IND4						.521		
Independence - IND2						.453		
Masculinity - MAS4							.687	
Masculinity - MAS2							.638	
Masculinity - MAS3							.548	
Masculinity - MAS1							.509	
Social inequality - IEQ2								.689
Social inequality - IEQ1								.615
Social inequality - IEQ4								.549
Social inequality - IEQ3								.409

Rotation Method: Promax with Kaiser Normalization.

*Rotation converged in 7 iterations.

Using the Statistical Package for the Social Sciences (SPSS) software an analysis of reliability was conducted using Cronbach alpha and including alpha if item deleted. Results from the analysis (Table 5) demonstrated internal consistency in Sharma's constructs.

Table 5.

Reliability analysis

Item	Valid cases (n)	Cronbach's alpha	N of items
Independence (IND)	1,261	0.815	4
Interdependence (INT)	1,261	0.789	4
Power (POW)	1,261	0.912	4
Social inequality (IEQ).	1,261	0.823	4
Risk avoidance (RSK)	1,261	0.712	4
Ambiguity intolerance (AMB)	1,261	0.790	4
Masculinity (MAS)	1,261	0.800	4
Gender equality (GEQ)	1,261	0.845	4

In the following section, we provide information regarding the two studies we conducted after confirming validity and reliability of our instrument. It is important to explain that we conducted the two different studies using the adapted version of Sharma (2010) instrument, one focused on all the questions with data from Spring 2014 and Fall 2014, and the other study using a pre-and-post test after analyzing our initial findings in the Fall 2015 with only uncertainty avoidance questions in first year engineering students. Uncertainty avoidance was selected because we only had access to include 8 questions in the survey, and that is the dimension that we were more interested in understanding further. In this paper, we divided the following sections by engineering study, and first year study to be able to present our studies more clearly.

3.4.2. Engineering study

3.4.2.1. Data collection procedures. After confirming validity and reliability of the survey, it was distributed online using Qualtrics. Invitation to participate was sent by email through the central office of assessment at a research institution during the Spring 2014 and Fall 2014 semesters. Data collection procedures were approved by IRB. Two reminders were sent. Students participating approved an electronically consent form on the first page

of the survey. Students took no more than 25 minutes to fill out the 38 questions survey. Data about GPA, demographics, major, and semester were collected. In addition, students could provide their email if they wanted to participate in a follow-up study regarding their responses.

3.4.2.2. *Sample.* The study collected data from 794 undergraduate engineering students. Table 6 provides detailed information about the sample.

3.4.2.3. *Data analysis.* Data were downloaded from Qualtrics and analyzed using SPSS. Descriptive statistics are presented. Creswell (2013) affirms that means, and standard deviations should be explained when analyzing results from a survey. In addition, inferential statistics were conducted. An analysis of variance (ANOVA), post-hoc tests, and t-tests were done to understand the differences in the responses of the students by engineering major. Detailed description of the results is presented in the results section in this paper.

3.4.3. First year study

After conducting our engineering study, based on the results we decided to further explore the uncertainty avoidance dimension. In order to determine how perceptions of the students regarding uncertainty avoidance changed during their first year in engineering, we were able to include Sharma's questions regarding uncertainty avoidance in the mandatory survey that first year engineering students take before and after their first semester. Based on the literature review, we hypothesize that there won't be differences between the pre-and-post test since students don't change their perceptions of national culture over one semester. Therefore, Hofstede's dimensions should be relatively stable over time. However, despite not expecting major changes in students' responses, we compared responses from

the beginning of the academic program, with students that were in the last part of their program to understand which dimensions were the ones that demonstrated more change.

Table 6.

Characteristics of the sample

Characteristic	Students n= 794	Percentage
<u>Discipline</u>		
Aerospace engineering	75	9.45%
Chemical engineering	57	7.18%
Civil engineering	71	8.94%
Computer science	80	10.08%
Electrical and computer engineering	187	23.55%
Engineering science and mechanics	26	3.27%
Industrial and systems engineering	154	19.40%
Material sciences engineering	24	3.02%
Mechanical engineering	89	11.21%
Mining engineering	19	2.39%
Ocean engineering	12	1.51%
<u>Gender</u>		
Female	187	23.55%
Male	565	71.16%
Prefer not to answer	42	5.29%
<u>Race/Ethnicity</u>		
American Indian	4	0.50%
Asian	104	13.10%
African American	21	2.64%
Hispanic	34	4.28%
Hawaiian native	1	0.13%
White	572	72.04%
Prefer not to answer	58	7.30%
<u>Level</u>		
Freshmen	180	22.67%
Sophomore	226	28.46%
Junior	166	20.91%
Senior	222	27.96%

3.4.3.1. Data collection procedures. The survey was administered online through their university's course management system. Data collection procedures were approved by IRB. Students had to take the survey as an assignment of their first year general engineering course. Students participating approved an electronically consent form on the first page of

the survey. We don't have access to information regarding how long was the survey, or how much time took for the students to fill out the survey. We only used the 8 questions from our survey that related to uncertainty avoidance.

3.4.3.2. Sample. The sample was formed from 1,330 first year engineering students at the same research institution. The students were part of the first year general engineering program and enrolled in the first engineering class they need to take. The course is called engineering exploration and meets two times a week for 1.5 hours.

3.4.3.3. Data analysis. Since the students had an identifier when taking the survey we had a paired sample that took the pre-and-post test. We conducted a paired-samples t-test to determine if their perceptions regarding uncertainty avoidance changed during their first semester in engineering. Students also reported their intended major so it was possible to identify students with the intention to pursue industrial and systems engineering, electrical and computer engineering, and computer science. Those are the disciplines that we are interested in study since we have a significant sample size in the engineering study.

3.4.4. Limitations

One limitation of the study is generalization of the findings. The data might not be representative of the majors studied. Neither can it be possible to make inferences of the engineering student population as a whole. The sample size of the study was limited; therefore, we recommend caution drawing conclusions from the study.

In addition, Hofstede's model did not provide enough information to be able to understand the differences between engineering disciplinary cultures in terms of his dimensions. As expected since the model was developed to measure cultural differences at the national level, therefore the instrument and the type of questions could be capturing information about the students' national cultural values rather than their academic cultural

values, therefore the information is limited to make inferences about the culture of the discipline in academic settings. Nevertheless, this study provides with valuable information to understand some aspects of students' perceptions of culture both at the national level and the disciplinary level. We were able to understand how some dimensions seem to be more dynamic in engineering students, and how despite that some disciplinary differences are small; we can use the information to inform future research.

Regarding the pre-and-post test, one limitation is the possibility of the familiarization with the test that can influence the students' results. However, the pre-test was taken in the first week of the semester and the post-test four months after, therefore, seeing the questions in the pre-test do not provide an advantage or a benefit for the students so this threat is minimal.

3.5. Results

In this section I will present the results for the two studies conducted. The first section has the results of the engineering study where we do some analysis based on the different engineering majors. The second section presents information regarding the first year study.

3.5.1. Engineering study results

In order to identify if Hofstede's theory of dimension of national culture maps to academic engineering disciplines, descriptive statistics representing how each major scored in all of the four dimensions are presented in Table 7. Note that the arithmetic means of the scores look very similar. To determine if there were significant differences in the responses of the students in each engineering major, a one-way analysis of variance (ANOVA) was conducted.

Table 7.

Scores by engineering major

Major	N	Individualism		Power Distance		Uncertainty avoidance		Masculinity	
		INT	IND	POW	IEQ	RSK	AMB	MAS	GEQ
Computer and electrical engineering	187	2.16	5.47	4.03	3.10	4.16	4.65	4.26	6.14
Computer science	80	2.36	5.64	3.85	2.77	4.38	4.53	4.22	6.19
Industrial and systems engineering	154	1.98	5.61	4.03	3.02	3.85	4.49	4.32	6.02
Aerospace engineering	75	2.14	5.74	4.12	2.93	3.98	4.37	4.21	6.05
Chemical engineering	57	2.03	5.58	4.06	2.82	4.32	4.73	4.07	6.19
Civil and environmental engineering	71	1.93	5.68	4.35	2.96	4.05	4.59	4.09	6.12
Engineering science and mechanics	26	2.14	5.53	4.08	2.81	4.25	4.82	4.32	6.11
Material science engineering	24	1.99	5.84	3.94	2.91	4.51	4.94	4.57	6.26
Mechanical engineering	89	2.09	5.76	4.04	3.07	4.23	4.56	4.17	5.96
Mining engineering	19	1.95	5.91	3.92	3.17	3.74	4.43	4.16	5.51
Ocean engineering	12	2.02	5.54	4.17	3.10	4.44	4.38	4.07	6.00

In order to do our analysis, we only considered the majors which samples were representatives (i.e. computer and electrical engineering, computer science, industrial and systems engineering, aerospace engineering, and mechanical engineering). There were no significant differences at the $p < 0.05$ level between majors in interdependence (INT), power (POW), social inequity (IEQ), gender equality (GEQ), and masculinity (MAS). However, some constructs reported significant differences that will be analyzed in more detail in the following section. Independence (IND) reported significant differences [$F(10, 783) = 11.28, p = 0.023$] between the scores in the engineering majors. The two constructs that compose uncertainty avoidance (UAI) had also significant differences between majors: ambiguity intolerance (AMB) [$F(10, 783) = 26.12, p = 0.002$] and risk aversion (RSK) [$F(10, 783) = 2.33, p = 0.010$]. A post-hoc analysis was conducted to identify which majors have differences.

We conducted post hoc comparisons using the Tukey HSD test because our data met assumptions of homogeneity. Results indicated that the independence (IND) mean score for computer and electrical engineering ($M = 5.47$, $SD = 1.855$) was significantly different than industrial and systems engineering ($M = 5.61$, $SD = 1.234$), aerospace engineering ($M = 5.74$, $SD = 1.171$), and mining engineering ($M = 5.91$, $SD = 0.995$). In addition, the post hoc comparison indicated that the ambiguity intolerance (AMB) mean score for industrial and systems engineering ($M = 4.49$, $SD = 1.505$) was significantly different from computer science ($M = 4.53$, $SD = 1.613$), electrical and computer engineering ($M = 4.65$, $SD = 1.387$). Similarly the risk aversion (RSK) mean score for industrial and systems engineering ($M = 3.85$, $SD = 1.453$) was significantly different than electrical and computer engineering ($M = 4.16$, $SD = 1.386$), and computer science ($M = 4.38$, $SD = 1.663$).

3.5.2. Results by academic year and major

Based on the quantitative data analyzed and the results observed regarding individualism and uncertainty avoidance it can be inferred that the dimensions should be researched in more detail. In order to determine when the changes in the scores in the dimensions are happening, t-tests were conducted in industrial and systems engineering, computer science, and electrical and computer engineering, comparing sophomore and seniors students. Sophomore and seniors were selected for several reasons: (i) senior students have a better understanding of the engineering major and have formed their perceptions about what the major is about; (ii) at the sophomore level students have their initial contact with the engineering major (first year corresponds to general engineering); and (iii) in the sample both levels have the higher representation. Based on the t-test results (table 8), students in electrical and computer engineering sophomores ($M = 4.04$, $SD =$

1.150) were associated with a significant lower score ($t(12) = -2.014$, $p=0.02$) on risk aversion than seniors ($M = 4.47$, $SD = 1.632$). The difference is even higher in ambiguity intolerance ($M=4.66$ in sophomores to $M=5.25$ in seniors). This variation is considered significant ($t(23) = 0.983$, $p=0.0145$). Computer science sophomores ($M = 4.21$, $SD = 1.172$) were associated also with a significant ($t(5.98) = 6.223$, $p=0.021$) lower score on risk aversion than seniors ($M = 4.63$, $SD = 1.237$). Regarding ambiguity intolerance, the score for seniors ($M = 5.25$, $SD = 1.061$) increased considerably ($t(17) = 1.789$, $p=0.03$) when compared to sophomores ($M = 4.66$, $SD = 1.377$) meaning that they are less comfortable with ambiguity when they advance in their program. In contrast, industrial and systems engineering seniors' scores ($M = 3.19$, $SD = 1.491$) on risk aversion decreased significantly ($t(33) = 1.879$, $p=0.041$) when compared with seniors ($M = 3.19$, $SD = 1.491$). Similarly, there was a significant decrease on ambiguity intolerance (Sophomores $M=4.62$ to Seniors $M=3.61$), meaning that in difference to ECE students, ISE students tend to get more comfortable with ambiguity and risk over time.

Table 8.

Uncertainty avoidance results by academic major and year

Major	Risk Aversion				Ambiguity Intolerance			
	Sophomore		Senior		Sophomore		Senior	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Computer science	4.21	1.172	4.63	1.237	4.66	1.377	5.25	1.061
Electrical and computer engineering	4.04	1.150	4.47	1.632	4.52	1.026	5.31	0.855
Industrial and systems engineering	3.73	1.164	3.19	1.491	4.62	1.455	3.61	1.599

Note: variations between results are significant at the 95% level

3.5.3. First year study

As previously mentioned, we were able to conduct a pre-and-post test with the first year engineering students during the Fall 2015. After collecting the data, using SPSS we conducted a paired samples t-tests so we could see how a particular student responses changed over time when they finished their first semester of engineering. Results from the paired-samples t-test by intended major on how students score in the two constructs that measure uncertainty avoidance are shown in Tables 9 and 10.

Table 9.

Pre-and-post test paired-samples t-test results for Ambiguity Intolerance (AMB)

Intended Major		n	Mean	Std. Dev.	t	df	Sig. (2-tailed)
Industrial and systems engineering	AMB PRE	272	4.61	1.218	1.163	279	0.097
	AMB POST	272	4.49	1.259			
Computer science	AMB PRE	102	4.85	1.174	1.129	101	0.262
	AMB POST	102	4.71	1.177			
Electrical and computer engineering	AMB PRE	314	4.48	1.356	2.328	142	0.211
	AMB POST	314	4.22	1.282			
Aerospace engineering	AMB PRE	79	4.74	1.132	1.056	98	0.294
	AMB POST	79	4.59	1.335			
Chemical engineering	AMB PRE	72	4.41	1.060	-0.254	23	0.801
	AMB POST	72	4.47	1.258			
Civil and environmental engineering	AMB PRE	145	4.95	1.122	0.651	46	0.622
	AMB POST	145	4.78	0.907			
Engineering science and mechanics	AMB PRE	51	4.76	1.198	0.017	111	0.986
	AMB POST	51	4.76	1.213			
Material science engineering	AMB PRE	62	4.79	1.242	0.999	87	0.321
	AMB POST	62	4.61	1.319			
Mechanical engineering	AMB PRE	205	4.45	1.126	2.212	41	0.366
	AMB POST	205	4.28	1.427			
Mining engineering	AMB PRE	9	4.44	1.303	-.0231	37	0.818
	AMB POST	9	4.48	1.336			
Ocean engineering	AMB PRE	19	4.46	1.196	-0.653	178	0.515
	AMB POST	19	4.53	1.395			

Table 10.

Pre-and-post test paired-samples t-test results for Risk Aversion (RSK)

Intended Major		n	Mean	Std. Dev.	t	df	Sig. (2-tailed)
Industrial and systems engineering	RSK PRE	272	3.74	1.205	-0.761	279	0.447
	RSK POST	272	3.80	1.0210			
Computer science	RSK PRE	102	4.04	1.206	-1.340	101	0.183
	RSK POST	102	4.20	1.193			
Electrical and computer engineering	RSK PRE	314	3.86	1.196	0.94	142	0.925
	RSK POST	314	3.65	1.213			
Aerospace engineering	RSK PRE	79	3.84	1.101	-0.057	98	0.954
	RSK POST	79	3.84	1.230			
Chemical engineering	RSK PRE	72	3.75	1.020	-0.292	23	0.773
	RSK POST	72	3.81	1.109			
Civil and environmental engineering	RSK PRE	145	3.67	1.171	0.350	46	0.729
	RSK POST	145	3.59	1.269			
Engineering science and mechanics	RSK PRE	51	3.83	1.196	-0.770	111	0.442
	RSK POST	51	3.91	1.277			
Material science engineering	RSK PRE	62	3.77	1.143	0.104	87	0.917
	RSK POST	62	3.75	1.185			
Mechanical engineering	RSK PRE	205	3.64	1.194	0.901	41	0.376
	RSK POST	205	3.33	1.267			
Mining engineering	RSK PRE	9	3.75	1.056	-1.102	37	0.314
	RSK POST	9	3.89	1.105			
Ocean engineering	RSK PRE	19	4.03	1.191	0.983	178	0.327
	RSK POST	19	4.13	1.369			

Based on the results of the paired-samples t-test, students do not have statistically significant differences in their scores for ambiguity and risk aversion when comparing their perceptions at the beginning of the semester and at the end. However, a t-test was conducted to determine if there is statistical significance in the differences between the scores for ambiguity and risk aversion of first semester general engineering students compared to senior engineering students in their respective majors, results are reported only for the majors that had significant differences.

Tables 11 and 12 shows the t-test results confirming that students in the first year of general engineering that have the intention to pursue industrial and systems, and electrical

and computer engineering, and computer science have significant differences in their ambiguity intolerance and risk aversion scores when compared to senior students in industrial and systems engineering, electrical and computer engineering, and computer science. Although students in the first year general engineering program have not officially entered the engineering majors, in the survey they responded what were the intended engineering majors they want to pursue. Therefore, for the analysis we were able to compare freshmen students that had the intention to pursue industrial engineering, with senior students in industrial engineering. A similar analysis was conducted for electrical engineering and computer science.

Table 11

Independent samples t-test results for Ambiguity Intolerance

Major		n	Mean	Std. Dev.	t	df	Sig. (2-tailed)
Industrial and systems engineering	Freshmen	272	4.49	1.259	3.122	182	*0.009
	Senior	95	3.61	1.599			
Computer science	Freshmen	102	4.71	1.177	1.438	157	*0.030
	Senior	57	5.25	1.061			
Electrical and computer engineering	Freshmen	314	4.22	1.282	-0.991	310	*0.017
	Senior	109	5.31	0.855			

- significant at the 95% level of confidence

Table 12

Independent samples t-test results for Risk Aversion

Major		n	Mean	Std. Dev.	t	df	Sig. (2-tailed)
Industrial and systems engineering	Freshmen	272	3.80	1.021	12	182	*0.025
	Senior	95	3.19	1.491			
Computer science	Freshmen	102	4.20	1.193	1.210	157	*0.041
	Senior	57	4.63	1.237			
Electrical and computer engineering	Freshmen	314	3.65	1.213	2.838	310	*0.012
	Senior	109	4.47	1.632			

- significant at the 95% level of confidence

In the following discussion section, we will describe in more detail how the results can inform the understanding of disciplinary culture in engineering majors. Furthermore, information about the use of Hofstede's theory of dimensions of national cultures in academic settings will be explained. Finally, limitations of this study will be addressed as well as implications for future research.

3.6. Discussion

Analyses of survey responses were initially focused on determining if Hofstede's dimensions of culture mapped to cultural differences in academic disciplines. From the initial dataset sample sizes for majors outside engineering were not representative. Therefore, the focus of this study turned to examining differences between engineering majors. Overall, all engineering majors studied (11) had similar scores regarding Hofstede's dimensions of culture. Nevertheless, results included significant differences between some majors (i.e. industrial and systems engineering, electrical and computer engineering, and computer science). Furthermore, we were able to identify that there were significant changes between students that had the intention to pursue the major in their first year, and students in their senior year in the engineering major. In this section, we will elaborate on each dimension based on the results obtained.

3.6.1. Individualism

According to Hofstede (2011) cultures can be described in terms of individualism or its opposite, collectivism. Individualism refers to the degree people in a system are integrated with other members of the system. This dimension is particularly important to understand disciplinary culture in engineering majors because there is a demand for engineers to be able to work collaboratively in teams and to solve problems with people who think and work differently (Rugarcia et al., 2000; Shuman et al., 2005; Tryggvason &

Apelian, 2006). Mean responses in Table 5 demonstrate that all engineering majors studied had similar scores regarding the two constructs that Sharma uses to analyze individualism (i.e. interdependence, and independence). We couldn't confirm the expected differences in the way students in industrial engineering for example approach teamwork, compared to other disciplines like mechanical engineering or computer engineering -based on the researchers' experiences. However, we consider that there should be differences in that dimension since the curricular structure of these majors is different. For example, ISE has a strong focus on teamwork, while in aerospace engineering or electrical and computer engineering, for example, there is a strong focus on individual work. Analyses presented provided information on statistical differences between industrial engineering, computer science, and electrical and systems engineering. Interestingly, the scores in computer science, and electrical and computer engineering are lower than the scores in industrial and systems engineering, a major that because of its curricular emphasis on teamwork was expected to have a higher score.

One recommendation regarding individualism is to do further research using a qualitative approach to understand students' experiences working in teams or in projects that require interdisciplinary collaboration. Understanding how engineering students perceive their individualism could provide information to develop pedagogical strategies (like team projects or grades) that promote collaboration, inclusion, and participation in collective spaces (like living learning communities).

3.6.2. Power distance

Hofstede (2011) defines power distance as the extent to which a given system supports unequal power distribution. This dimension addresses inequality defined from the perspective of the members of the system in lower power positions. Results from the study

did not provide information on differences between students in engineering majors regarding this dimension. In this dimension, power (POW) and inequality (IEQ) had similar scores in every engineering major. Further qualitative research of these disciplines could usefully identify how students perceive their interactions with faculty members, preferences for autonomy, communication patterns, and role of the follower (student) and the leader (faculty) in the discipline.

3.6.3. Masculinity

According to Hofstede (2011), masculinity refers to the distribution of values between genders. Masculine cultures are associated with assertiveness and competition, while feminine cultures are associated with caring and modesty. This dimension is very important for the understanding of disciplinary cultures in engineering majors because it may provide information that helps change the masculine perception of the engineering field. It can also provide information to improve inclusion and diversity, and to make engineering schools more welcoming. However, results from the survey did not provide information on differences in cultures in terms of the two constructs developed by Sharma to study masculinity. Every engineering major that participated in the study had a high score, indicating that indeed all of the engineering programs were associated with assertiveness and competition. Using Hofstede's survey for data collection might not be effective capturing the students' perceptions on this dimension. Again, a qualitative approach may yield more informative results.

3.6.4. Uncertainty avoidance

Uncertainty avoidance refers to a culture's tolerance for ambiguity (Hofstede, 2011). It indicates to what extent members of the culture feel comfortable or uncomfortable with the lack of structure in different situations. Cultures with high uncertainty avoidance will

try to establish strict behavioral codes, laws and rules to avoid ambiguity and uncertainty (Hofstede, 2011). This was the dimension that provided more information to understand engineering majors. In addition, this dimension is very important because it can determine how the disciplines are promoting their students' abilities to "think outside the box," change rules, and work with other disciplines that are less familiar to them –conditions required in every engineering discipline.

As we described in the results section, there were several differences regarding risk aversion and ambiguity –the two constructs developed by Sharma to measure uncertainty avoidance- in industrial and systems engineering, electrical and computer engineering, and computer science. Engineering and industrial and systems engineering have lower scores of both RSK and AMB, therefore this discipline is more comfortable with less structure, less clear rules, and taking more chances. On the other hand computer and electrical engineering, and computer science has higher scores of RSK and AMB, meaning that they will be less comfortable in situations that demand uncertainty. Similarities between results of electrical and computer engineering and computer science can also be attributed to the fact that the disciplines are in the same academic department. Therefore, it is expected that ECE students have similar responses despite their specific major.

In addition, we were able to identify that students' perceptions of uncertainty avoidance don't change during the students' first year. During the first year at our study site, engineering students are all together taking general engineering classes. In the second year each student selects a major and starts taking classes in their respective academic discipline. Students in electrical and computer engineering and computer science scored higher in uncertainty avoidance over time. The opposite trend occurred with students in

industrial and systems engineering. Students' scores decreased over time when they were in their academic discipline.

3.7. Future work

This study describes a quantitative investigation of disciplinary culture in engineering majors. We confirmed validity and reliability of Sharma's instrument. The results confirmed expected national level scores, however, the model did not map differences in engineering majors. Nevertheless, it would be interesting to do further research on how Hofstede's constructs –that are valid to measure national culture- can be useful to guide future studies about disciplinary culture using different data collection methods. One next step is to conduct an extensive literature review on Hofstede's theory to more fully understand the critiques to his model and how to best address weaknesses.

In addition, further research with students in industrial and systems engineering, computer science, and electrical and computer engineering is planned. These majors provided interesting information that is worth exploring further, and it may be fruitful to use a qualitative approach to identify how the students perceive and understand their majors in terms of cultural differences.

Findings provided information that can have an impact in research and practice. For research, there is value in engineering education in the process of using frameworks developed for other disciplines. In our research we explained the process of using Hofstede's model –developed for understanding national cultures- into academic disciplines. Results from the study confirmed the validity of using Hofstede's to measure national culture, however it did not provide with much information on how it maps to academic disciplines. One recommendation when using the instrument is to provide contextualization in the introduction. If students are able to understand the bounds of the

culture that we are trying to measure, it will be more likely that the responses given are focused on the academic perceptions of the culture rather than their individual perception of what they value and believe.

For research, it is important to note that the research process involves several steps of testing and trying new approaches that sometimes can not provide the expected results, nevertheless, it provides with valuable information that needs to be shared with the academic community.

Results also provide implications for practice. First, it is important for faculty members and administrators to understand the dimensions of national culture (U.S.) shared by students. By understanding dimensions of national culture, faculty members can explain some of the reasons for students' behaviors and can provide guidance on what things can motivate students and what academic barriers students' might have because of their culture. Understanding that the United States culture tends to be individualistic, avoid uncertainty, and accept power distance, can help faculty members shape the way they design their learning environments. For example, if it's known that the students will tend to be individualistic, and teamwork is something that we want to promote in our students, we will need to think of extra efforts to promote effective collaborative environments.

In conclusion, this study explores a model of dimensions of culture developed by Hofstede and its application into academic disciplines. As demonstrated in the results, the model didn't explain disciplinary differences between engineering majors. The lack of disciplinary differences is attributed to our hypothesis that based on the theory the model was going to measure culture at the national level. Despite that we didn't test if the responses compared to the scores of the United States in Hofstede's dimensions, it was possible to see a pattern that is similar in the responses of the students. For example, the

U.S. maps as an individualistic society, and results in our study are that students have high independence, and low interdependence. A similar situation can be observed in masculinity, risk aversion and ambiguity –when compared to uncertainty avoidance, and power and equity – when compared to power distance. Nevertheless, the information provided in this study can help the engineering education field to create culturally sensitive strategies that enhance the characteristics described in this research, therefore, change processes can be more effective.

3.8. Acknowledgment

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4. Chapter 4. Manuscript 2: Use of Hofstede's Framework: A Review of the Literature on Implementation and Critiques

4.1. Abstract

Understanding disciplinary engineering culture is necessary to make informed decisions regarding engineering education. This literature review focuses on evaluating Hofstede's model of dimensions of national culture to identify its possible use in academic settings to better understand disciplinary culture. After reviewing more than 90 articles it was possible to summarize the main critiques of Hofstede's model and its successful application in different context. The three main categories of critiques are (i) conceptual, (ii) methodological, and (iii) the incorrect use of Hofstede's constructs. Information is provided about several replications of Hofstede's initial study, including uses of his constructs to successfully investigate culture in different contexts. Suggestions on how to use his theory to understand engineering disciplinary culture are provided.

Keywords: Hofstede's dimensions, innovation, literature review, engineering disciplinary culture

4.2. Introduction

Given the central role engineering plays in technology innovation, 21st-century engineering programs have been consistently called upon to help students develop the attitudes, mindsets, and practices that can drive innovation (Committee on Science Engineering and Public Policy 2006; National Academy of Engineering, 2004; National Academy of Engineering 2005). Despite such calls to promote creativity as “an indispensable quality for engineering”(National Academy of Engineering, 2004) (p.6),

however, programs in the U.S. have been generally slow in developing pedagogies that successfully promote the desired behaviors.

Change remains challenging, however, as engineering programs struggle to find the balance between the high-risk pursuit of innovation and the traditional problem-solving approach of producing functional, reliable applications. At the same time, engineering curricula nationally have been largely limited. That is, even as the profession, the students, the available technologies, and our understanding of learning have all changed over time, many engineering faculty keep teaching as they were taught (Chubin et al., 2008; Tryggvason & Apelian, 2006). Changes over the last 30 years have been relatively modest; the core structure and the programmatic content of most engineering programs remain very close to those of the 1960s (Tryggvason & Apelian, 2006). This resistance to change may, in fact, help explain the field's persistent struggle with attracting and retaining members of underrepresented populations—populations whose diversity could greatly contribute to innovation.

As the April 2014 special issue of the *Journal of Engineering Education* suggests, approaches to transforming engineering education vary widely, including promoting changes in curriculum and pedagogy, rewriting promotion and tenure policies, and acknowledging teaching excellence (Besterfield-Sacre et al., 2014); using experiential exposure to commercially directed innovation and entrepreneurship so students can take control of their careers (Weilerstein & Shartrand, 2008); promoting collective efficacy and value beliefs to improve individuals' competence (Matusovich et al., 2014), and using local data to bridge the research-to-practice gap and design plans that accelerate the adoption of effective teaching practices (Matusovich et al., 2014).

In this study, we focus on change via an exploration of the culture of teaching and learning in engineering. This approach is consistent with Matusovich et al.'s argument that not only personal, but also collective beliefs and values are essential in supporting change. As Godfrey and Parker (2010) note, calls to address change in engineering education through a cultural lens date back at least to the mid-1990s and encompass studies of national cultures, institutional and campus cultures, faculty cultures, gender and cultures, and more. Culture has been a particularly prominent framework used in relation to underrepresented groups, particularly women, in engineering; lack of diversity in the field is often attributed to the masculine, individualistic, and function-oriented culture of engineering (Dryburgh, 1999; Faulkner, 2000, 2007; Henwood, 1998; Kunda, 2009; Powell et al., 2004; Tonso, 2006, 2007).

In addition to specific work on the culture of engineering, a number of studies have looked at differences in academic disciplines with respect to teaching, learning, and practice. One of the earliest and most notable, of course, is Snow (1959)'s *Two Cultures*, positing the growing divide between the "literary intellectuals" and the "physical scientists". Since then, a range of social science and education researchers have used empirical research to more fully explore differences and similarities among disciplines. Work by Becher (1981, 1989) focused on analyzing disciplinary differences from the micro-level (academic departments). Bradbeer (1999) looked to the macro-level (interaction of different disciplines) with work based on understanding differences in disciplinary epistemologies, discourses, traditions for teaching and learning, and students' preferred learning approaches and styles. Donald (2002) case studies examined structures that professors and students create to construct and use knowledge. Nulty and Barrett (1996) focused on experiential learning models, and Neumann (2001); Neumann, Parry,

and Becher (2002) examined the nature of teaching, teaching and learning processes, and teaching outcomes across the different disciplines to propose broader disciplinary classifications.

As noted earlier, much of the work on disciplinary cultures seeks to describe differences in ways of knowing and learning, but does not necessarily link those epistemologies to particular kinds of outcomes. At the same time, work by Kim and McNair (2011) exploring interdisciplinary conceptual design teams suggests that students in fields that emphasize functionality (e.g. engineering) rather than creativity (e.g. industrial design) express higher levels of uncertainty avoidance. That is, engineering students were less comfortable with and more likely to avoid uncertainty and ambiguity – a mindset that can significantly limit design and innovation in engineering.

Uncertainty avoidance is one of the four dimensions of national culture posited by Hofstede in his work focused on cross-national and organizational cultures (Hofstede et al., 2010b). Hofstede's original analysis yielded four dimensions of culture, or "values that distinguished countries (rather than individuals) from each other." (Minkov & Hofstede, 2012) **Power Distance** addresses the degree to which those with less power in a given system (workplace, family) may support and expect unequal power distribution. **Uncertainty Avoidance/Acceptance** addresses the degree to which members of a culture can operate comfortably with uncertainty. **Individualism/Collectivism** addresses the relationship between individuals and the larger group. *Masculinity/Femininity* refers to the continuum representing how emotional roles are distributed across genders.

Because of its roots in cross-cultural workplace studies, Hofstede's model has the potential to offer particular insights relative to understanding disciplinary engineering culture. In the previous chapter we explained how Hofstede's model didn't provide

information on disciplinary differences, nevertheless given the value of Hofstede's work across national cultures, the literature characterizing academic disciplines as culture, and the arguments suggesting that change within engineering education requires attention to culture, we consider important to further understand Hofstede's theory in terms of its limitations and value in understanding academic disciplines' culture.

These gaps point to the need to understand 1) the main critiques of Hofstede's model, 2) the ways in which it has been adapted (successfully or not) to different contexts, and 3) strategies to minimize the limitations associated with adapting the model to investigate cultural traits across academic disciplines. Toward these goals, this article provides a review of the literature on Hofstede's model to address two research questions:

RQ2: What are the primary categories of critiques of Hofstede's survey instrument?

RQ3: How can these limitations be minimized to make Hofstede's model appropriate for adaptation to an academic setting?

In the following literature review, we start by summarizing Hofstede's 30 years research and survey development. We then explain the methodology that guided our literature review. Next, we describe the main categories of critiques of Hofstede's model, focusing on representative authors in each category. These categories include a) conceptual critiques; b) methodological critiques; and c) the incorrect application of Hofstede's model. In the following section, we review how some authors have successfully used Hofstede's theory and addressed critiques, making it possible for us to propose the use of Hofstede's dimensions to inform our next steps in our research to understand engineering disciplinary culture.

4.3. Overview of Hofstede's Research

Hofstede introduced his conceptualization of culture after developing his theory of cultural dimensions in the mid-1960s. In his initial study, he analyzed the cultural differences among nations by surveying employees at IBM in more than 50 countries regarding their personal values. Hofstede's framework was first published in 1980 in his book *Cultural Consequences: The dimensions approach*. Hofstede (1980) initial definition of culture is developed based on his observations of the desired and desirable values of IBM's employees around the world. He described culture as a "collective programming of the mind," describing cultural patterns as rooted in value systems of major groups of individuals that become stabilized over long periods of time as acceptable ways of thinking. His definition of culture has evolved over time, and in more recent books Hofstede et al. (2010a) define culture as patterns of thinking, feeling, and acting that every human being carries. Even more recently, Minkov and Hofstede (2013) defined culture as a "system of shared meanings that may be unique to a particular society or a group of societies" (p.4).

Hofstede (1980)'s original analysis yielded four dimensions of culture based on problems that are inherent to all societies: (a) social inequality, including the relationship with authority, (b) the relationship between the individual and the group, (c) ways of dealing with uncertainty and ambiguity, which turned out to be related to the control of aggression and the expression of emotions, and (d) concepts of masculinity and femininity: the social and emotional implications of having been born as a boy or a girl. Based on these issues Hofstede (1980) labeled his dimensions of culture as ***power distance*** (from small to large), ***individualism*** (versus collectivism), ***uncertainty avoidance*** (from weak to strong), and ***masculinity*** (versus femininity).

Hofstede et al. (2010a) expanded to six dimensions in later studies. The two newer dimensions are not included in our study because they appear to have less bearing on disciplinary culture: *long-term/ short-term orientation* address virtues stemming from teachings of Confucianism such as “thrift” or “respect for tradition,” and *indulgence/restraint* represents a continuum of how satisfied and happy individuals in a certain nation are with their lives. While these dimensions may be useful delineators for national cultures, the values addressed are less relevant to disciplinary contexts because they refer only to culture at the national level.

Hence, in our study and in this literature review, we focus on the original four dimensions:

- Power Distance addresses the degree to the extent to which the “less powerful members of institutions and organizations within a country expect and accept that power is distributed unequally” (Hofstede et al., 2010b) (p.61). Notably, this dimension addresses inequity as defined and endorsed from below (i.e. the followers rather than the leaders). Exploring disciplines via this dimension can address patterns of student and faculty relationships, preferences for autonomy, communication patterns, and preferred problem types.
- Uncertainty Avoidance/Acceptance addresses the degree to which members of a culture can operate comfortably with uncertainty. According to Hofstede et al. (2010a) in cultures with high uncertainty avoidance, unstructured situations (novel, unknown, surprising, etc.) are perceived as intimidating; these cultures seek to minimize such situations via both legal controls (e.g. laws, rules, security measures), and religious philosophies that rest on absolute truth. Cultures that accept uncertainty, in contrast, tolerate diverse opinions, have fewer rules, and

adopt more relativist philosophies. Exploring disciplines via this dimension can address students' abilities and willingness to collaborate, especially in interdisciplinary teams of unfamiliar territory, as well as their openness to creative formulations of problem solutions.

- Individualism/Collectivism addresses the relationship between individuals and the larger group. In an individualistic culture, individuals are loosely connected: everyone is expected to operate independently and people do not strongly identify with a group norm. In collectivist cultures, people are tightly connected and consolidated into cohesive in-groups with strong emphasis on group norms and unity (Hofstede et al., 2010b). Exploring disciplines via this dimension can address participation of underrepresented populations in engineering, where collectivist interventions, such as living and learning communities, has proven to be effective social and academic support networks.
- Masculinity/Femininity refers to the continuum representing how emotional roles are distributed across genders, with assertive roles aligned with the masculine pole of the continuum and caring roles aligned with the feminine pole. Notably, in Hofstede's studies, women show less variation by culture than men; i.e. men are more assertive and competitive in masculine cultures, while women exhibit similar levels of caring in both masculine and feminine cultures. Masculine cultures thus experience a greater gap between men's and women's roles. Exploring disciplines via this dimension may address women's participation in the masculinized culture of engineering that move beyond the metaphors of "pipeline" and "chilly climate."

4.4. Methods

Following systematic review procedures proposed by Gough, Oliver, and Thomas (2012), our goal was to identify a representative set of articles presenting critiques to Hofstede's theory of cultural dimensions, as well as implementation of his theory in different settings. The search was done simultaneously using several databases. Using the search terms "Hofstede," "Cultural dimensions," "Culture," and "Critique" in any field, the search focused on articles published in peer-reviewed journals between January 1983 and December 2013. We decided to start in January 1983 because was after the publication of Hofstede's first book. This 30-year period was selected intentionally in order to include relevant work related to the implementation and use of Hofstede's theory and to achieve saturation. In the initial search 94 articles were found. Analyzing the full text of every article refined the search. The final articles were chosen for demonstrating all the following selection criteria:

1. The author(s) presented some type of critique of Hofstede's theory
2. The author(s) used Hofstede's instrument to analyze cultural differences
3. The author(s) used Hofstede's theoretical framework in their study.

In addition some articles were excluded due to misconceptions of the use of Hofstede's instrument (i.e. using Hofstede's survey to explain accounting principles). Other articles mentioned some of the proposed criteria in the abstracts; however, in the full paper there was no evidence of such affirmations so they were excluded as well. Using this criteria selection process resulted in 59 articles qualified for the study. We implemented a peer-review process after our initial findings were obtained that allowed us to make adjustments and minimize our initial bias. The process was conducted by three faculty members and three graduate students, who reviewed the articles and provided input on the

different sets of criteria regarding the critiques to Hofstede's theory. The main information regarding each critique is presented in the next section.

4.5. Critiques of Hofstede's Research and Survey Development

In the following sections, we present the main critiques found in the literature about Hofstede's theory of cultural dimensions and conclude with an overview of successful applications.

4.5.1. Conceptual Critiques

Culture itself is notoriously difficult to define (McCurdy et al., 2004; Miroshnik, 2002; Williams, 1983, 1985) with definitions ranging from Edward Burnett Tylor's assertion that culture is a complex whole (including knowledge, beliefs, morals, law, habits, and capabilities) that is acquired by every person belonging to a society; to definitions of culture as the reflection of the way a certain group of people perceive, appraise, and experience the world (Klein, 2004). Some authors measure culture as learned behaviors, others as abstractions from behaviors, and still others measure culture as the relation between selected objects and their meanings to people. Culture exists only in the mind according to some, so it can only be measured with self-reporting; according to others culture can be measured with observation of behaviors and events in the external world (Kluckhohn & Kelly, 1944; Kroeber & Kluckhohn, 1952; Segall et al., 1966). Hofstede et al. (2010b) defines culture as the way people perceive their values in terms of the desirable and the desired (i.e. beliefs on how the world should be versus what people desire for themselves). The desirable refers to what is right and wrong, acceptable or not by society. On the other hand, the desired is about individuals, and the things that they want for themselves. While society establishes norms, policies, and rules about what is perceived as good or positive in the desirable, the desired values can be subjective. This subjectivity in

the spectrum of values and definitions points to one of the problems of identifying and measuring culture.

Many critiques focus on Hofstede's choices and assumptions in conceptualizing culture. For example, Baskerville (2003), who is an accounting and finance scholar, argued that culture should be conceptualized using anthropological and sociological traditions, and noted that Hofstede's work stems from and is cited most in psychology and management-related disciplines. This approach has led, according to Baskerville, to the flawed assumptions that: (i) nation can be equated with culture, (ii) culture can be quantified; and (iii) the observer can be outside the culture. McSweeney (2002b) also challenged the approach that underlies Hofstede's cultural dimensions, critiquing the assumption that IBM organizational culture does not vary across nations. McSweeney (2002b) also challenged the assumption that people's behavior in the workplace is representative of the other aspects of their lives; rather, people sometimes behave differently in the workplace because of social pressures or organizational culture. Finally, McSweeney argues that Hofstede's cultural dimensions lack contextual considerations and thus lack systematic causation regarding for several reasons: (i) Hofstede does not consider the influence of sub-cultures enough, (ii) he relies on a single explanatory variable to explain cultural causation, leaving out the possible explanations that non-national cultures and the non-cultural could contribute to the behaviors, and (iii) Hofstede assumes that people belonging to a national culture are homogeneous.

Ford et al. (2003) state similar objections, that Hofstede's work assumes that culture is static over time, and since the cultural dimensions fall along national boundaries there is an implicit assumption that national culture is homogenous (without sub-cultures). Similarly, Fang (2010) and others (Everett et al., 1982; Pascale & Maguire, 1980) argue

that 21st century globalization has given rise to a paradoxical movement of cultures and management practices in which modern people have multicultural identities and multicultural minds beyond their national cultures. According to Fang (2012) the perception of cultural learning as extending “longitudinally from one’s own ancestors within one’s own cultural group” (p.26) is not adequate anymore.

In addition, there is a concern that culture evolves over time (Fernandez et al., 1997; Søndergaard, 1994; Wu, 2006) and Hofstede’s perceptions of cultural dimensions should change as well. Several authors propose that the dimensions developed in Hofstede's theory correspond only to the period of time in which the study was conducted (1960s) and those dimensions have been incorrectly treated as if they do not change over time (Wallace et al., 1999).

Finally, Hampden-Turner and Trompenaars (1997), in line with Baskerville, critique Hofstede’s choice to measure culture in mathematical language, and in linear and exclusive categories. They claim that because culture has a dynamic and adaptive nature it is not possible to correctly quantify it based on numeric dimensions and matrices (Hampden-Turner & Trompenaars, 1997). Instead, they argue, culture is a qualitative variable, and culture has meanings that depend upon the context and external factors (Baskerville, 2003). Single elements of the context cannot dictate meaning to explain the whole phenomenon(Hampden-Turner & Trompenaars, 1997).

4.5.2. Methodological critiques

Hofstede’s model has been subject to several critiques based on methodological grounds, including lack of internal consistency, replicable dimensions, validity, and finally problematic wording of the dimensions themselves.

4.4.2.1. Internal consistency. Several authors have argued that Hofstede's model lacks internal consistency when using the dimensions to measure cultural differences. In order to examine the empirical validity of Hofstede's cultural framework, J. Blodgett, G. et al. (2008) conducted an exploratory study in which the results indicated that the cultural framework, when applied at the individual unit of analysis, is lacking reliability and internal consistency. Similarly, Spector et al. (2001) affirm that Hofstede's research does not provide information on internal consistency or reliability of his instrument. The authors conducted a study on 23 of the 40 countries that Hofstede's theory was based on using his original instrument. Out of 115 Cronbach alpha calculated, only 13 achieved the 0.7 coefficient that is considered the minimum acceptable alpha (Santos, 1999) concluding that Hofstede's instrument lacks internal consistency.

4.4.2.2. Replications of the dimensions. Other researchers have tried to replicate Hofstede's framework and found that some dimensions don't hold up. Fischer et al. (2010) critique the stability of the country-level dimensions in Hofstede's model, arguing that multiple steps in the analysis generated a significant amount of lengthy sequences of probabilities, which needed further cross-validation. Similarly, Smith et al. (1996) were not able to replicate the masculinity-femininity and the individualism-collectivism dimensions. Chanchani and Theivanathampillai (2002) evaluated Hofstede's dimensions in comparison to other cultural typologies and found that Hofstede's model was lacking transcendence in the level of analysis, and Smith et al. (1996) were not able to replicate the masculinity-femininity and the individualism-collectivism dimensions.

4.4.2.3. Validity. Validity in quantitative research refers to the process of accumulating evidence to determine whether a researcher can obtain meaningful information to make useful inferences from data collected, which means that the test is

measuring what the instrument is intended to measure (J. Creswell, 2013; Goodwin & Leech, 2003; Moskal et al., 2002). Moskal et al. (2002) suggest that validity is obtained when there is evidence that supports interpretations and the appropriateness of how those interpretations are used. Validity is considered to be the most fundamental consideration in the development of evaluation tests (Goodwin & Leech, 2003). There are several types of critiques regarding validity that will be discussed in this section: first face validity, then construct validity, and last external validity.

In order to determine the face validity of Hofstede's instrument, J. Blodgett et al. (2008) asked the participants of their study (157 students and faculty members) to map Hofstede's survey questions to the dimensions of culture that he developed. On average respondents matched the question to the correct dimension only 41.3% of the time. According to the authors, this demonstrated that Hofstede's instrument is lacking face validity.

Regarding construct validity, Søndergaard (1994) identified a number of articles that pointed to three major constraints in Hofstede's study:

1. Data collected between 1968 and 1973 are no longer valid;
2. The use of employees of one company as a basis for conclusions about national dimensions;
3. The proposition that human values are conditioned solely by national culture ignores the potential influence of a variety of other contextual factors; and
4. The use of attitude surveys alone does not constitute a valid basis for this type of research (Schooler, 1983; Smucker, 1982).

Chiang (2005) raises methodological concerns regarding the external validity of Hofstede's findings, claiming that generalizability may be affected by the fact that survey

respondents are from a single large multinational corporation (IBM). Fernandez et al. (1997) argue that the information collected in his study may be biased by the fact that the sample belonged to a single company. This affirmation is supported by Søndergaard (1994) who found that several researchers using Hofstede's model cite this issue as a main weakness. Reasoning that people working in a company tend to develop an organizational culture that may affect their national cultural beliefs, it is possible that employees at IBM around the world had developed some organizational values that affected their responses (Smircich, 1983). Generalizability of the findings is also affected by gender and occupation; in Hofstede's study mostly male respondents working in marketing and servicing were in the sample (Everett et al., 1982).

Finally, Triandis (1982) considers the use of a single method of data collection for measurement as too limited, especially when analyzing complex concepts like cultural dimensions. The author suggests using a multi-method research design in order to obtain reliable information from different sources that can explain the results. This affirmation was accepted and shared by Hofstede himself.

4.4.2.4. *Wording of the dimensions.* Chiang (2005) raises concerns regarding Hofstede's labeling of the dimensions. For example, the term masculinity–femininity has generated some criticism because it may have a sexist tone that is inaccurate and not appropriate, and power-distance can be interpreted, inappropriately, as an indicator of inequality. Adler, cited by Chiang (2005), suggested that it would be necessary to change the label of the power-distance dimension to “career success/quality of life” in order to address this criticism.

4.5.3. Incorrect application of Hofstede's constructs

Finally, some authors have critiqued not Hofstede's theory but its applications as

researchers have attempted to apply a theory of national cultures to the individual level. Brewer and Venaik (2012) affirm that the national culture dimensions' characteristics, scales and scores are often used in research and teaching as if they apply to individuals, when they do not. They highlighted the misapplication of Hofstede's national culture dimensions at the individual level of analysis in both research and teaching. This phenomenon was defined by Piantadosi et al. (1988) as the *ecological fallacy*, i.e. to wrongly assume that relationships observed for groups will hold for individuals. Items in Hofstede's instrument were highly correlated at the national level, but at the individual level correlation was very low or inexistent and sometimes contradictory (Grenness, 2012). We believe this is one of the most important critiques to using Hofstede's model into academic settings. As it is, Hofstede's dimensions would provide information on culture at the national level rather than at the disciplinary level.

In the following section we describe successful application of Hofstede's dimensions and provide information on how despite the ecological fallacy being a limitation to use Hofstede's in academic settings, his dimensions can still be valuable to inform our research. Based on this limitation there is a need to include more theoretical frameworks when developing data collection instruments for the next phases of this research to complement the limitations that Hofstede's model has.

4.5.3. Examples of successful application of Hofstede's theory

Hofstede et al. (2010b) have conducted six major replications of his study in several countries. In addition, many other researchers have also successfully applied the framework in a variety of studies. Hoppe (1998) tested the construct validity, obtaining data from 1500 respondents in 19 countries and was able to use statistical analyses to demonstrate validity and reliability of Hofstede's model using a different sample (i.e. managerial,

professional, political, and academic elites). Shane et al. (1995) were also able to replicate 3 of the 4 dimensions in a study conducted to identify the relationship between national culture and national preferences for innovation championing strategies. They had a sample of 1228 individuals in 30 countries. The authors confirmed the reliability of Hofstede's scales with Cronbach alpha, and validity was established by (i) consulting the instrument with experts in cultural psychology, engineering, and innovation, (ii) using statistical procedures like factor analysis and correlations, and (iii) comparing results of the research with previous results of Hofstede's original work. In another study, Chiang (2005) used Hofstede's model to understand how cultural differences can shape the types of rewards employees desire the most. However, the author explains that contextual factors may influence these decisions as well.

Similarly, Merritt (2000) incorporated Hofstede's survey questions to the Flight Management Attitudes Questionnaire (FMAQ), and collected data for four years using a sample of 9,417 pilots in 26 airlines in 19 countries. The author replicated Hofstede's study and was able to demonstrate the reliability and validity of his survey. Merritt (2000)⁸³ first did a pilot testing of the questions, followed by a correlational analysis between the pilots' responses and Hofstede's original country scores for each dimension. A second analysis was conducted by correlating all items in the database—including Hofstede's items with the new items written for the pilot survey—with Hofstede's index scores. Finally, a cluster analysis was done with the data obtained in the study that generated clusters that were similar to what was expected according to Hofstede's dimensions, demonstrating validity of Hofstede's model.

De Mooij (2010) replicated 3 of the 4 dimensions in a study investigating cultural differences in consumer behaviors. Hofstede's instrument was used in combination with a

marketing questionnaire, obtaining results in which three dimensions correlated significantly with the country scores of Hofstede's initial study and reliability was demonstrated with an internal consistency analysis. In addition, De Mooij (2010) conducted a literature review of Hofstede applications, finding that his dimensions are increasingly used as a valid conceptual framework to classify and explain the influence of culture on several different research topics outside their original setting.

Another replication of Hofstede's theory was conducted by Mouritzen and Svava (2002) in a study of the cultural context of leadership in politicians. They were able to replicate 3 of Hofstede's 4 dimensions and correlated the form of government with Hofstede's index. They also conducted a cluster analysis that allows them to demonstrate validity of Hofstede's model in a political context. Van Nimwegen (2002) also replicated Hofstede's study in banking settings and was able to demonstrate validity using a cluster analysis and correlations of his data with Hofstede's original results. Similarly, Ardichvili and Kuchinke (2002) used Hofstede's instrument to understand leadership styles and cultural values among managers and subordinates in independent companies in 6 countries. In this study, the reliability tests proved internal consistency in the instrument.

Yoo et al. (2011) successfully developed a scale based on Hofstede's model to measure the dimensions of national culture (individualism, power distance, uncertainty avoidance, and masculinity) at the individual level. The authors modified Hofstede's original instrument and improved it using the support of several experts that were familiar with Hofstede's theory. The improved instrument was piloted and probed with several responses obtaining internal consistency in all the four dimensions with ranges of Cronbach alpha from 0.71 to 0.96. In addition to demonstrating reliability the authors conducted an exploratory and a confirmatory factor analysis with data from three separate samples,

obtaining the expected results that established construct validity. In addition, validation was established by applying the instrument in three different countries, on different populations, always obtaining similar results when doing statistical procedures like factor analysis.

Brewer and Venaik (2012) explain that despite their criticism of Hofstede's theory regarding the ecological fallacy, the model is valuable to explain the national-level phenomenon. Similarly, Grenness (2012) affirms that "avoiding the ecological fallacy is possible when the aggregated data are collected from groups or samples which are assumed to be or known to be homogenous, e.g. sharing dominant cultural values" (p.80). It is necessary to understand the population that will be analyzed and having knowledge of the homogeneity or heterogeneity in order to draw methodological solutions to the individual behavior based on aggregated data.

Hofstede (2002) himself replied to most of the criticism in a reply written to McSweeney (2002a). First, he stated that most of the concerns that McSweeney pointed out were addressed in a posterior edition of *Culture's Consequences* (2001). One of his criticisms was that surveys are not an optimal way of researching cultures; Hofstede acknowledges that affirmation. He suggests using several methods to obtain trustworthy information regarding culture. His argument is that surveys are a valid method to do research in sociological sciences and when supported by other methods can provide the required results to understand complex phenomenon like culture. He also agrees with the concern that nations should not be the unit of analysis for studying cultures, but explains that researchers do not have many options considering that boundaries of cultures cannot easily be observed, and determined. He affirms: "they are (nations) usually the only kind of units available for comparison and better than nothing" (p.2).

Hofstede (2002) also addressed the concern that the data from the IBM study may

be obsolete, explaining that the dimensions have their roots in patterns of behavior that are centuries-old and sociologically consistent over time. He also pointed out that only the data that remained stable across two subsequent surveys were used for the development of his theory. He affirms that over the years his instruments have passed multiple test of validity and reliability, in applications both external and internal to his team, over a period of 30 years (At-Twajiri & Al-Muhaiza, 1996; Cheung & Chan, 2010; Elenkov & Manev, 2005; Entrekin & Chung, 2001; Giacobbe-Miller et al., 2003; Heuer et al., 1999; Huettinger, 2008; Li et al., 2007; Liu et al., 2009; Prašnikar et al., 2008; Rarick & Nickerson, 2008; Reisinger & Crotts, 2010; Soares et al., 2007; Tang & Koveos, 2008; Twati, 2008; Yoon, 2009).

A final concern addressed by Hofstede himself was about the development, quality, and quantity of the cultural dimensions. He states that the dimensions are independent in concept and statistical analysis. He affirms that the current dimensions should be validated with external measures of correlations. He is continuously working in the development of new categories and evaluating the validity of the current ones.

Hofstede's theory has proven to be valid and reliable to measure national culture in different contexts. Some of the limitations of his model have been addressed by other researchers and himself. However, it has limitations to be used in academic disciplines, especially to measure disciplinary cultural differences in terms of how students perceive their major. Hofstede's dimensions are valuable to inform what aspects of culture should be explored beyond the traditional teaching and learning aspects of the disciplines, and can provide a different perspective when developing data collection instruments to understand disciplinary culture.

4.6. Discussion

Based on these studies we argue that Hofstede's methodology is valid and reliable to measure culture in different contexts. Several authors have been able to use his model to study cultural differences from the perspectives of employees in different corporations, and in different fields. The model is able to capture what people value and how they feel about their work, and how they act and react under different circumstances.

However, several limitations to Hofstede's model were identified in the literature. There are conceptual critiques based on the complexity of understanding culture. However, since culture is such a complex construct there is value in using a model that can provide a broader understanding of the concept. There are also methodological critiques regarding validity, consistency, and reliability of Hofstede's model. Some researchers argue that haven't been able to conduct research using his model and obtain reliable, and valid results. However, they don't provide information on how they conducted their designs. In addition, there are several authors that have been able to demonstrate it. There are also critiques regarding using Hofstede's model –designed to measure culture at the national level- to understand cultural differences at another level, and under other sub-cultural contexts like academic disciplines. This critique can explain why we weren't able to find disciplinary cultural differences using Sharma's version of Hofstede's survey.

Despite its critiques, Hofstede's model have been used and applied under several different contexts to understand culture in terms of his dimensions. The model has proven to be one of the most successful models to study culture in a corporative environment. We consider that the corporate perspective of understanding culture from the values, feelings, and ways of thinking that the people that share the culture have it is important in order to better understand engineering disciplinary culture.

We are particularly interested in using the original four cultural dimensions (individualism, uncertainty avoidance, power distance, and masculinity) to inform how to understand engineering academic culture. These four dimensions are constructs that respond to social issues shared by almost every person belonging to any type of culture (Hofstede & Hofstede, 2001; Hofstede et al., 2010b), and these constructs can be useful not only to understand disciplinary engineering culture quantitatively but also can inform qualitative data collection, allowing students to have a deep reflection on their experiences with their discipline regarding every dimension that will provide information on the culture of the discipline beyond epistemological perspectives.

In terms of the four dimensions, we believe that the dimension of *Individualism* is particularly important to understand disciplinary culture in engineering majors because there is a demand for engineers to be able to work collaboratively in teams, and to solve problems with people who have different perspectives (Rugarcia et al., 2000; Shuman et al., 2005; Tryggvason & Apelian, 2006). *Uncertainty avoidance* can provide valuable information on how engineering students feel about thinking outside the box, changing rules, and working with other disciplines that are unknown to them. *Power distance* can provide information regarding student and faculty member interactions and relationships, preferences for autonomy, communication patterns, and role of the follower (student) and the leader (faculty) in the discipline. *Masculinity* is also very important for the understanding of disciplinary cultures in engineering majors because it may provide information that helps change the masculine perception of the engineering field. It can also provide information to improve inclusion and diversity, and to make engineering schools more welcoming.

Hofstede's model also allows understanding of disciplinary cultures in engineering students based on their individual perceptions about their values and behaviors beyond the classroom. Hofstede et al. (2010b) affirm: "values, more than practices, are the stable element in culture, comparative research on culture starts from the measurement of values" (p. 28). Most of the previously discussed models that address differences in academic or disciplinary cultures describe accepted practices in the discipline, rather than the values that the members of the academic units shared. The survey questions linked to Hofstede's constructs ask them to think about how they respond to situations and what they value.

In engineering majors for example, different academic departments with very similar curricula and course structures can perform very differently because of the varying perceptions that members of the department may hold regarding their disciplinary culture (Tierney, 1988). Hofstede's dimensions can provide information on how students can be similar or different in the way they behave in their disciplines in terms of culture with constructs that are not directly related to academic settings (i.e. individualism, power distance, uncertainty avoidance, and masculinity).

Similarly, Hofstede's theory can provide information regarding how engineering majors can function better not only with other engineering majors, but also with collaborators from other disciplines. Hofstede's theory can be valuable in overcoming the main issues proposed by Bradbeer (1999) as barriers to interdisciplinarity: (i) differences in disciplinary epistemology, (ii) differences in disciplinary discourses, (iii) differences in disciplinary traditions of teaching and learning, and (iv) differences in students' preferred learning approaches and styles. By understanding Hofstede's dimensions of disciplinary culture in engineering majors, it will be possible to help faculty members develop different

teaching strategies to accommodate different learning styles, and also to provide information to students to help them become self-aware learners.

4.7. Conclusions

We conducted this review to determine whether Hofstede's model would be a rigorous and useful framework for investigating cultural dimensions of academic disciplines, with the goal of discovering patterns that may aid our understanding of innovation in engineering education. Overall, this review of the literature resulted in three main categories of critiques: conceptual and methodological critiques, and the incorrect use of his model. The critiques in the first category stemmed from differing epistemological views of culture, which is unanimously agreed to be a complex phenomenon that is extremely difficult to measure. To address this category of critiques, it is important to explicitly situate our approach in terms of social science research generally and to acknowledge that the model stems from cultural psychology specifically. Also, we agree with assertions that culture is not linear or sufficiently measured by quantitative means alone, and that it is critical to avoid generalizing patterns observed in groups versus individuals. Secondly, we believe that critiques related to validity and reliability of the quantitative instrumentation are counter-balanced by a multitude of research applications that have confirmed validity and reliability or addressed issues with revisions. Research pursuant to these critiques has included further cross-validation measures, including addition of contextual data and rigorously tested revisions of the instrument. The final category of critiques, misuse of Hofstede's constructs, is easily addressed with careful attention to research questions and implementation methods. An effective antidote to each of these categories is using rigorous methods that include triangulation of data that provides contextual detail.

Indeed, in addition to Hofstede's development and testing of his own model across a span of 30 years, variations of his model and instrument have been tested by researchers with different research goals in different settings (Hofstede & Hofstede (2001) describe over 200 in *Culture's Consequences*). For instance, in addition to validity and reliability demonstrated by other researchers in settings similar to Hofstede's original study, the instrument has been used to investigate cultural perspectives of leadership (Ardichvili & Kuchinke, 2002; Mouritzen & Svava, 2002), consumer behavior (De Mooij, 2010), employee rewards preferences (Chiang, 2005), and flight management attitudes (Merritt, 2000). These implementations have expanded the reach of the instrument beyond employees of the same company to a wide range of sample populations, including academia (Hoppe, 1998) and utilizing input from cross-disciplinary experts in cultural psychology, engineering and innovation (Shane et al., 1995).

After reviewing over 20 adapted versions of Hofstede's surveys, we have decided to use Sharma (2010)'s version due to the author's rigorous process of scale development and validation, and established reliability, and construct, convergent, discriminant, nomological, and predictive validity. We also are triangulating the quantitative data with qualitative interview data that will enable us to characterize students' perceptions of cultural differences in disciplines and mitigate effects described as the ecological fallacy. Hofstede's model informs the construction of the interview protocol, along with constructs of teaching and learning metrics adapted from Bradbeer (1999) and Nulty and Barrett (1996). We conclude that, when supported by other methods, Hofstede's well-researched and vetted framework is a valid approach for better understanding cultural patterns in academic disciplines, and that the perspectives gained could help engineering educators better understand engineering disciplinary culture.

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5. Chapter 5. Manuscript 3: Understanding engineering disciplinary culture: A comparison between disciplines

5.1. Abstract

Culture represents a set of values and norms that dictate how people behave, interact with each other, learn, shape their personality, and live. Academic disciplines have cultures that help shape the way students understand what the discipline values, teaching and learning processes in the discipline, and the norms and accepted behaviors that help students form their professional identity. The purpose of this study is to understand engineering disciplinary culture from the students' perspectives and to see how it compares with other disciplines. Data were collected qualitatively using an interview protocol informed by three theoretical frameworks. Participants were students from two engineering disciplines (Industrial and Systems Engineering and Electrical and Computer Engineering), industrial design, and marketing. Findings provided information on how students perceive what the major values, how it is taught, how it is learned, why they learn, and how they may use what they learn in their professional careers. Engineering students perceive their major as a traditional hard-science technical major where ability to obtain the right answer, solve problems, and understand how things work are valued, and learning comes from memorization and repetition of the information provided by faculty members in lectures where there is low participation. Implications for research, policy, and practice are provided.

5.2. Introduction

Culture represents a set of values and norms that dictate how people behave, interact with each other, learn, shape their personality, and live (Hofstede, 1980; Namenwirth &

Weber, 1987; Smircich, 1983). There are elements like symbols, values, norms, beliefs, behaviors, attitudes, self-perceptions, cognitive abilities, and stereotypes (Minkov & Hofstede, 2013) that have specific meaning for specific groups, and through these common elements, groups share the same culture. In order to comprehensively understand the learning processes and educational experiences in engineering majors, it is critical to understand the culture of the engineering discipline and how it compares with other disciplines. Furthermore, engineering disciplinary culture shapes the way students understand how to become a professional engineer, how to relate with their professors and peers, how to approach learning engineering topics, and how to apply their undergraduate knowledge in engineering settings.

The Accreditation Board for Engineering and Technology (ABET), in accordance with industry and academic leaders, has established that engineering schools should produce engineers who are problem solvers, creative thinkers, globally aware, and able to work effectively in interdisciplinary teams (Shuman et al., 2005; Terenzini et al., 2001; Woods, 1997). However, many of the efforts regarding improving engineering classrooms in terms of the required skills that industry demands in engineering students are seen as a sacrifice in the development of discipline-specific problem-solving skills (Clough, 2004; Tryggvason & Apelian, 2006).

According to Vest (2008) engineers in their daily work face the stress of competing in the fast-paced world of change that is known as the “knowledge-based global economy of the twenty-first century” (p. 235). The engineering field is expected to solve global problems, to help countries improve their economies with leadership in innovation, and to make the world more connected and accessible (Mihelcic et al., 2006; Redish & Smith, 2008; Rugarcia et al., 2000; Sheppard et al., 2008; Tryggvason & Apelian, 2006; Vest,

2008). There is a need that engineering education improve the engineering field by providing with the graduates able to fulfill those needs; however, providing the design and delivery of quality engineering education that fulfills industry and societal needs is a very complex task (Sheppard et al., 2008). In order to improve the field, it is necessary to understand it first. We argue that by understanding how students perceive their engineering disciplinary culture can provide information about the root of this problem. In addition, we also need to understand how students in other majors outside engineering understand their disciplinary culture, to make sure that we can see actual differences and students are describing cultural aspects of the discipline rather than cultural aspects at a higher level (university culture, national level culture).

The purpose of this study is to understand students' perceptions of engineering disciplinary culture and how it compares with other disciplines. To study culture at the disciplinary level we developed a qualitative study informed by Hofstede's constructs to measure dimensions of culture, complemented by Nulty and Barrett (1996)'s classification of disciplines based on students' learning styles, and Bradbeer (1999)'s classification of disciplines based on teaching and learning processes.

After conducting a quantitative study and a literature review on Hofstede's theory, in this study we are collecting data through conducting qualitative interviews to understand how undergraduate engineering students perceive their disciplinary engineering culture. Results in this manuscript will be used to complement the results from the other two manuscripts. The research question guiding this manuscript is:

RQ4: How do undergraduate engineering students perceive their disciplinary engineering culture in comparison to students in marketing, and industrial design?

5.3. Literature review

5.3.1. Academic Culture

Academic culture according to Clark (1997) refers to the agreement on core values and common frameworks shared by members of academic institutions. In addition, Becher (1981) suggests that the set of disciplines in academic settings possess a common culture: “their ways of construing the world and the people who live in it are sufficiently similar for them to be able to understand, more or less, each other's culture and even, when necessary, to communicate with members of other tribes (disciplines)” (p.152). One of the ways that academic culture is shared by faculty members despite their discipline is with the concept of “academic freedom” (Clark, 1997). In addition, academic culture has strong meaning for academics despite their disciplines in the sense that the academic system has been able to bring together academic excellence, scientific preeminence, and universal access in order to pursue knowledge adjusting to student and society needs (Clark, 1997). Academic culture provides guidance on what is accepted by students and faculty members on how to behave, learn, interact, teach, and collaborate in the academic discipline (Peterson & Spencer, 1990).

Austin (1990) explains that academic culture provides overarching integrative values that link faculty members and students beyond their disciplines and institutions. The author affirms that the purpose of higher education is to “pursue, discover, produce, and disseminate knowledge, truth, and understanding” (p.62); therefore, students during their time at school and faculty members during their academic career value, understand, and act according to the purposes of higher education. However, Graubard (1997) affirms that academic culture is also about the recognition, integration, and collaboration of different disciplines (Graubard, 1997).

Despite academic culture having an impact on students and faculty members in the way they understand their role in academic communities, specific academic disciplines are considered the best organizational structure to facilitate the pursuit of knowledge (Austin, 1990; Graubard, 1997). Disciplinary cultures provide a set of values, behaviors, characteristics, and social rules that are accepted by the discipline and shared by all their members and that go beyond the shared purposes across academic culture. The differences between disciplines will have more power than the similarities that academic culture provides to every member of the system (Austin, 1990) in that academic culture provides general rules on how to achieve the purpose of higher education, but disciplinary cultures provide the rules on how to become a member of a specific discipline. Disciplinary cultures are more important for developing the identity of students in terms of how and what they need to learn, and how they need to behave to success in their professional careers. They also provide the rules for how faculty members should conduct their teaching, research, communicational, mentoring, and role modeling processes.

5.3.2. Disciplinary culture

From a cultural perspective, Ylijoki (2000) suggests that universities do not form an homogeneous whole, but an heterogeneous entity with different “small worlds” (p. 339). The author explains that disciplines vary cognitively and socially. Thus, it is possible to assume that disciplines have their own traditions, cognitive biases, norms, values, forms of interactions, pedagogical strategies, and lifestyles. Students who belong to a particular discipline will share similar disciplinary cultures, and they will share the same differences in contrast to other disciplines (Ylijoki, 2000).

Austin (1990) explains that in the academic profession, the primary unit of “membership and identification” is the discipline (p. 63). Understanding of disciplinary

cultures can provide information about the acceptable norms of conduct and acceptable behaviors in a respective field in terms of the language, style, symbols, traditions, and appropriate professional activities, which shape how the discipline is experienced and understood. Disciplinary differences impact the lives of faculty members, students, and professionals in every field (Austin, 1990), hence the understanding of disciplinary cultures becomes necessary in higher education. Research conducted by Becher (1994) identified different systems of classifying disciplines based mostly on teaching and learning processes, but these systems stemmed from the perspectives of faculty members and administrators. Since the culture of a discipline is the central source for identity development at a faculty and student level (Austin, 1990; Becher, 1994), its comprehension must include the students' perceptions.

According to Becher (1994) understanding those differences between disciplines is key to the higher education system, and he suggests that disciplines are the life-blood of higher education. Disciplines provide the main organizing base for academic institutions; therefore, there is a need to understand each discipline in terms of its culture.

Greenhalgh (1997) defines disciplinary culture understanding as the process of studying academic disciplines in terms of the control of its knowledge, organization, production, and the social practices that maintain such control. Disciplinary cultures create a lot of differences between faculty members and students that go beyond the similarities of the academic culture. Variations across disciplines focus on the way students learn, interact with peers and faculty, solve problems, communicate, participate in and outside the classroom, and understand their academic discipline. In addition, variations across disciplines can be found in the way faculty members teach, conduct research, communicate,

interact with peers, interact with students, mentor, and behave in their academic discipline (Greenhalgh, 1997).

Several authors have studied disciplinary cultures and have established disciplinary differences from different perspectives. For this study, we used the frameworks proposed by Bradbeer (1999) and Nulty and Barrett (1996) to complement Hofstede (1980)'s framework. In the following section, we present more details about each theoretical framework.

Bradbeer (1999) presented a summarized outline of disciplinary differences based on Kolb's model of learning processes and differences in teaching. Similarly, Nulty and Barrett (1996) used the same framework to define disciplinary differences in terms of teaching and learning. The authors suggested that there are four different dimensions present when learning is being developed, including a transitional one. The dimensions are soft/applied that focuses on concrete experience, soft/pure that focuses on reflective concrete experiences, hard/applied that focuses on active experimentation and abstract conceptualization, and hard/pure that focuses on abstract reflections and observations, and the transitional dimension. Disciplines in this category are changing over time and shifting their epistemological beliefs.

This framework presents a different approach to categorizing disciplinary differences from pedagogical and epistemological approaches. However, the only perspective analyzed in most of them is the faculty members' perspective not the students' perceptions and values. Furthermore, the frameworks—which were developed almost two decades ago—were designed based on how the faculty members described their thinking, research, and teaching processes based on classroom settings and experiences, or research practices, all factors that have evolved considerably over time. In addition, all these studies

generalize engineering as a whole and don't consider differences between engineering majors. Therefore, we think it is necessary to complement these frameworks with a framework validated and developed to measure dimensions of culture. Hofstede's model provides dimensions of culture based on people's perceptions of what they value. Although the model was developed to measure national culture, and we used it in academic settings, it provided useful information in developing an interview protocol able to capture information about what the students believe and value beyond their experiences with just the daily practices in the classroom.

Hofstede (1980)'s framework yielded four dimensions of culture based on the problems that were inherent to all societies: (a) social inequality, including the relationship with authority, (b) the relationship between the individual and the group, (c) ways of dealing with uncertainty and ambiguity, which turned out to be related to the control of aggression and the expression of emotions, and (d) concepts of masculinity and femininity: the social and emotional implications of having been born as a boy or a girl. Based on these issues Hofstede (1980) labeled his dimensions of culture as *power distance* (from small to large) that can help explain how students understand authority in the classroom, and faculty-student relationships, *individualism* (versus collectivism) that can help explain how students understand collaboration with other students and interactions with other disciplines, *uncertainty avoidance* (from weak to strong) that provides insights on students' comfort levels with structure and clear rules (or vice versa), and *masculinity* (versus femininity) that can provide information regarding students' perceptions of gender equality in engineering.

The dimensions are defined by Hofstede (1993) as:

- Power Distance addresses the degree to the extent to which the “less powerful members of institutions and organizations within a country expect and accept that power is distributed unequally” (Hofstede et al., 2010; p.61). Notably, this dimension addresses inequity as defined and endorsed from below (i.e. the followers rather than the leaders) (Hofstede, 1993; Hofstede et al., 2010a). Exploring disciplines via this dimension can address patterns of student and faculty relationships, preferences for autonomy, communication patterns, and preferred problem types.
- Uncertainty Avoidance/Acceptance addresses the degree to which members of a culture can operate comfortably with uncertainty. According to Hofstede et al. (2010a) in cultures with high uncertainty avoidance, unstructured situations (novel, unknown, surprising, etc.) are perceived as intimidating; these cultures seek to minimize such situations via both legal controls (e.g. laws, rules, security measures), and religious philosophies that rest on absolute truth. Cultures that accept uncertainty, in contrast, tolerate diverse opinions, have fewer rules, and adopt more relativist philosophies. Exploring disciplines via this dimension can address students’ abilities and willingness to collaborate, especially in interdisciplinary teams of unfamiliar territory, as well as their openness to creative formulations of problem solutions.
- Individualism/Collectivism addresses the relationship between individuals and the larger group. In an individualistic culture, individuals are loosely connected: everyone is expected to operate independently and people do not strongly identify with a group norm (Hofstede et al., 2010a). In collectivist cultures, people are

tightly connected and consolidated into cohesive in-groups with strong emphasis on group norms and unity (Hofstede et al., 2010a). Exploring disciplines via this dimension can address participation of underrepresented populations in engineering, where collectivist interventions, such as living and learning communities, has proven to be effective social and academic support networks.

- Masculinity/Femininity refers to the continuum representing how emotional roles are distributed across genders, with assertive roles aligned with the masculine pole of the continuum and caring roles aligned with the feminine pole. Notably, in Hofstede's studies, women show less variation by culture than men; i.e. men are more assertive and competitive in masculine cultures, while women exhibit similar levels of caring in both masculine and feminine cultures. Masculine cultures thus experience a greater gap between men's and women's roles (Hofstede et al., 2010a). Exploring disciplines via this dimension may address women's participation in the masculinized culture of engineering that moves beyond the metaphors of "pipeline" and "chilly climate."

Hofstede's dimensions of culture can provide information on students' perceptions of what they value in the discipline. Nulty and Bradbeer frameworks provide information regarding the epistemological perspective of disciplinary cultural differences, especially in regards to how knowledge is built and transmitted in the discipline. Hofstede's constructs can complement this perspective and provide information from a business perspective on how students act, think, and feel in their major, what they perceive as valuable and important in the major, and their perceptions of what is accepted as the norm.

5.4. Methods

The purpose of this study is to understand how students perceive their disciplinary

engineering culture and how it compares to marketing and industrial design. Since our primary objective is to understand student experiences regarding what they value as the norm in their disciplinary culture, qualitative methods that provide rich descriptions are appropriate (J. Creswell, 2013; Leedy & Ormrod, 2005). We used thematic analysis methods (Braun & Clarke, 2006; Robson & McCartan, 2016) to investigate student experiences in their majors regarding cultural aspects like teaching, learning, faculty-students interactions, work, evaluation, and norms and values. Data were collected from undergraduate students from two engineering programs (i.e. industrial and systems engineering (ISE), and electrical and computer engineering (ECE)), and industrial design, and marketing, in a large research-focused state university in southeast United States. Specifically, we conducted interviews with participating students over the course of two consecutive semesters (Fall 2015, Spring 2016).

We used data collected from a previous quantitative study, theoretical frameworks of culture (Hofstede et al., 2010b), and teaching and learning differences (Bradbeer, 1999; Nulty & Barrett, 1996) to inform the data collection protocol, and to guide the qualitative analysis. The interview protocol was piloted, and modifications were done based on discussions with a research team conformed by four graduate students and four faculty members.

5.4.1. Thematic Analysis Methodology

Thematic analysis is defined by Braun and Clarke (2006) as a method of identifying, analyzing, and reporting patterns within qualitative data. According to Robson and McCartan (2016) thematic analysis is a generic qualitative method not linked to any particular theoretical perspective. Since we are not using a singular theoretical framework, and are interested in identifying, analyzing, and reporting the patterns of our interview data,

we believe the use of thematic analysis is appropriate to guide our study. Robson and McCartan (2016) suggest that thematic analysis can be used to better understand “experiences, meanings and the reality of participants” (p. 474). In addition, thematic analysis seeks to describe patterns across qualitative data to understand a phenomenon in question (Braun & Clarke, 2006). The phenomenon we want to understand in this study is how undergraduate engineering students perceive their disciplinary culture and how it compares to other disciplines, based on their experiences and beliefs.

Coming from a constructivist epistemology, our purpose is to understand how engineering students seek understanding of their subjective experiences in the world in which they live and work (i.e. the discipline). Our goal as researchers is to provide rich descriptions of the students’ perceptions of their experiences and look for the complexity of their views (J. Creswell, 2013). According to Guba and Lincoln (1994) in constructivism, participants socially construct the meaning of their experiences, and findings are created by the interactions between the researcher and the respondents. We developed an interview protocol that allowed us to obtain deep and rich information regarding how engineering students perceive their discipline in terms of cultural constructs. Our interactions with the participants provided us with a unique perspective on the discipline, and findings were constructed based on their individual perceptions of a similar discipline, and how it compares with the perceptions of participants in other disciplines using an ongoing process themes and codes development. Coding and the developing of themes is central to qualitative research (Robson & McCartan, 2016), and the differences with thematic analysis is that is not wedded to a particular theoretical framework. In our case we are combining the use of theoretical frameworks developed by Hofstede et al. (2010b), Nulty and Barrett (1996), and Bradbeer (1999); therefore, the use of thematic analysis is

appropriate to guide our analysis process.

5.4.2. Participants

The participants of this study were students from a large research-focused state university in the southeastern United States. We had 6 participants from Industrial and Systems Engineering (ISE), 6 from Electrical and Computer Engineering (ECE), 6 from Marketing (MKT), and 6 from Industrial Design (IDS). We decided to select those majors from the college of engineering for several reasons. First, the departments are innovative, large, and highly ranked relative to other departments nationwide. Second, both locally and nationally, these two departments are at opposite ends of the diversity spectrum, with ECE among the least diverse departments and ISE among the most diverse. In addition, Industrial Design and Marketing are considered to be opposite majors to engineering according to Nulty and Barrett (1996)'s classification of disciplines. Third, from the quantitative study conducted, the majors had considerably different results in Hofstede's constructs of culture. Finally, the researchers have years of experience teaching courses in the engineering majors including an interdisciplinary class with MKT and IDS students. From our own experience, the four majors have significant differences in the way they form their professional identity and understand their disciplinary culture; therefore, we predicted that by understanding the four different majors we can have a better understanding of the engineering disciplinary culture.

Participants were invited to participate voluntarily in the interview, and were compensated with \$25 for their time. Two researchers went to different classes at the junior and senior level to recruit students. We selected junior and senior level because we wanted students who had spent more time in their program, and therefore, could be able to provide the experiences of the students in their discipline. Recruitment procedures and material

were approved by IRB. Participants were recruited by email and using in-class recruitment. After demonstrating interest, the participants were asked to fill out a screening survey (Appendix C). The survey had only three questions asking about how they perceived the importance of being good at their major, their feelings toward being a part of the program, and the importance of doing well in their classes. The survey also asked for the gender of the participant. We used the screening survey to be able to target students who had different perceptions regarding these questions, as well as having a balance of genders. More information on gender is shown in Table 13.

Table 13.

Characteristics of the participants

Discipline	Gender	Level
Electrical and computer engineering (n=6)	Male: 5	Junior: 3
	Female: 1	Senior: 3
Industrial and systems engineering (n=6)	Male: 3	Junior: 2
	Female: 3	Senior: 4
Industrial design (n=6)	Male: 2	Junior: 1
	Female: 4	Senior: 5
Marketing (n=6)	Male: 1	Junior: 2
	Female: 5	Senior: 4

Although participants were not asked to identify demographic details, it is important to note the general demographics of the participating students in engineering, who were predominantly white males, which is very typical of engineering majors. The low gender diversity observed in ECE is representative of the relatively low gender diversity of this particular engineering program. Gender issues pertaining to engineering education was not an intended aspect of this study, and therefore discussion of gender will be limited in this paper; however it is still important to take note of the gender context that this study is situated within.

5.4.3. Interview protocol development

Data were collected using semi-structured interviews. The interview protocol was informed by theoretical frameworks of culture, and teaching and learning differences informed by Hofstede et al. (2010b), Bradbeer (1999), and Nulty and Barrett (1996). For example, Hofstede's dimension of individualism is measured in Sharma's instrument by asking questions regarding how people would rather depend on themselves than others. From Nulty and Bradbeer models there are questions related to who is responsible for the learning process, or how collaboration influence teaching and learning. Those types of questions led us to ask in our protocol questions related to the students' classroom experience in terms of motivation to share with others, on the individual vs. group focus of homeworks and exams, on how collective is the learning, and how collaborative is the professional future that they envision. A detailed table explaining how Hofstede's constructs map to Nulty and Bradbeer model and influence our interview protocol is provided in appendix D.

The first version of the interview protocol was piloted with 4 graduate students. We conducted 5 initial interviews to test the interview protocol. Those interviews were not included in our study since the main purpose was to improve the questions and procedures of our interview protocol.

After conducting the 5 pilot interviews, data were openly coded looking for Hofstede's four dimensions of culture and patterns of teaching and learning. The transcripts were coded by four different graduate students, and then several meetings were conducted to discuss the findings. The initial discussion was based on how the researchers defined the four constructs of Hofstede's theory, and how they coded information regarding the dimensions of teaching and learning. For example, we had some confusion regarding if

some statements were falling under the individualism category, or the power distance. We as a team agreed on some indicators to make sure we were all analyzing the information in the same way. For individualism, we agreed that if the students mention taking the initiative on their own, it would relate to individualism. On the other hand, if the professor initiated the activity, then we would code it as power distance.

After coding and discussing the 5 pilot interviews, we suggested modifications to the interview protocol. The biggest suggestion was regarding how to capture program culture through student perceptions. We focused on figuring out how to get the general perception of the students, rather than individual's perceptions. We suggested to not have them compare to one another; but rather look at how the majority of the students in the engineering major compared to other engineering majors, and focus on the things they believe are acceptable, valuable, and typical of the discipline. Four faculty members reviewed the protocol with the recommendations and agreed on the final version. The protocol was submitted to IRB for consideration and approved with minor suggestions.

Although we started the interview protocol development with Hofstede's initial dimensions, the questions evolved more into teaching and learning processes (Bradbeer, 1999; Nulty & Barrett, 1996); however, we recognized the importance of using Hofstede's dimensions to inform the development of some of the questions. For example, the question about preference for open-ended problems or problems with clear rubrics provides information on how students move between accepting the concrete vs. the abstract, and is also highly related to Hofstede's construct of Uncertainty Avoidance. The final interview protocol is included in Appendix E.

5.4.4. Data Collection

As described above in the participants' section, students were recruited by email and

in class. After being selected, students were contacted by email to set a time and place of their preference. The interviews were conducted in a private location. A consent form was developed (Appendix F) and read to the students before the interview started. After discussing the consent form the students signed it. The compensation of \$25 for participation was paid with a pre-paid Visa card. After receiving the compensation and signing the consent form, the interviewer started audio recording the interview. Interviews lasted between 45 minutes up to 55. There were no interviews that went further than 55 minutes.

5.4.5. Data analysis

Data were analyzed using a thematic analysis approach. According to Robson and McCartan (2016), thematic analysis is a constructivist method to analyze qualitative data that focuses on the ways in which experiences, meanings, and realities, are the effect of a range of discourses of participants in a particular group. We are trying to understand experiences and meanings of engineering students regarding how they perceive their disciplinary culture and how it compares to other majors. Thematic analysis is considered by Braun and Clarke (2006) as a “flexible and useful research tool, which can potentially provide a rich and detailed, yet complex account of data.” (p.5).

According to Braun and Clarke (2006), the process of conducting thematic analysis starts during data collection. The authors explain that researchers should be aware of issues of interest like possible patterns of themes. In addition Robson and McCartan (2016) affirm that thematic analysis is an ongoing process of going back and forward between the data, the analyses, and the notes that the researchers have taken.

The analysis process is inductive and the themes and codes emerge from the interaction of the researcher with the data (Robson & McCartan, 2016). During our data

collection and data analysis process we were very aware of the data, and the themes that were emerging from it, we took several notes and memos, and went back to our transcripts several times to revise the information.

Following thematic analysis procedures (Braun & Clarke, 2006; Robson & McCartan, 2016), most of the recordings of the interview were transcribed by the researchers to increase familiarization with the data. Pseudonyms were used to ensure anonymity of the participants, and some information like name of courses, professors, and institutions were changed. Notes taken during the interview were included when analyzing the data to facilitate the development of memos. The MaxQDA software was used to code the interview line by line. Robson and McCartan (2016) recommend the use of a qualitative data analysis software to have a single organized data storage location, to have quick and easy access to the coding system, to make sure there is a consistent coding scheme, and to be able to analyze differences, similarities and relationships between the codes developed. Codes were developed and two different researchers compared initial codes and agreed on the coding system. Once all parts of the data were coded, codes were grouped based on their similarities into themes. To maintain trustworthiness two researchers coded independently all the interviews in ISE and grouped the codes into the themes developed. Using MaxQDA it was possible to establish inter-rater reliability by having a visual representation of the codes. Researchers discussed until agreement on the codes that didn't match.

A codebook was developed based on the comparison of the codes and the themes. Table 14 shows information about the first level of codes and the themes that emerged from the data. The themes represent the main topics that we designed when developing the interview protocol. Therefore, the main areas where our data are being analyzed come from

the process of using Hofstede, Nulty, and Bradbeer, and the data that emerged matched those patterns.

During the analysis there were more levels of sub-codes and every time a new code or theme emerged, we went back to the transcripts already coded to make sure new codes and themes were not left outside the initial analysis. During this inductive process, there were several memos that were taken into consideration when developing and establishing the relationships networks between themes, and the connection between the data, the research question, and the theoretical considerations.

In Table 12 we list the themes, the first level codes of each theme, and the definition of the code, an extended version of the codebook that includes all the sub-codes can be seen in appendix G. According to Braun and Clarke (2006), in thematic analysis it is important to be clear regarding what is considered a pattern that leads to a code, therefore defining what the code mean for the researchers is necessary.

Table 14.

Codebook

Theme	Sub-theme/Code	Definition
What attracted you to the major?	Job Opportunities	Interest in having a profession with diverse and several job options after graduation
	Financial	Interest in having a profession that offers high salaries and several monetary benefits
	Interaction with people	Interest in being in a field that emphasizes the need to interact with others and to have people skills
	Perceived as good at it	Interest in the major because of early demonstration of ability in courses related to engineering (math, science, programming)
	Gender balance	Interest in a profession that provides similar opportunities for gender minorities
	Parent influence / role	Interest in following parents or role model steps. Even if parent or role model is not in the same profession, interest in following advice on going into the field.

Theme	Sub-theme/Code	Definition
What does the major value? Values	Interpersonal Skills/Collaboration	Ability to work well with others. Professional skills, like communication, teamwork, interdisciplinary.
	Wanting to learn	People with a desire to learn and understand how things work.
	Getting a Good Grade/One right answer	Correctness, and ability to follow the clear rules provided step by step in order to get the right answer that will provide the student with the good grade.
	Develop professional network	Take the time to know professors, and peers in the major to develop a professional network that will help with future career plans.
	Prof. and technical skills (Balance)	Having a balance between having technical skills and professional skills.
	Creative thinking	Ability to think outside the box and provide innovative solutions to solving problems
	Know what to do	Ability to always be able to solve problems under any contexts
	Accreditation	Students' attending accredited institutions and going into accredited engineering programs
	Ethics	Ability to consider the ethical impact of decisions made in the professional workplace
	Knowledge transfer	Ability to use theoretical knowledge into real-world situations in professional environments
How it is taught? Teaching process	Pedagogy	Pedagogical strategies used by the instructor in the classroom (active learning, discussion-based, lecture)
	Grading Process	Different strategies used to grade assignments on an individual and group based.
	Faculty Student Interactions	Different strategies used in the major regarding how students communicate, interact, and collaborate with their instructors. Approachability and encouragement to participate.
	Assignments	Types of assignments typically used in the major to identify students' achievement of learning outcomes
	Encouragement to participate	Strategies used for the instructor on the learning environment that motivates (or not) students participation in class with their opinions and points of view
	Class rules	Structure of the class regarding what is valued and acceptable. Includes class norms, complexity, and deadlines.
	Team interactions	Using of group work as part of the teaching process. Description of how teams develop interactions, and their working process.
How do you learn? Learning process	Hands-on activities	Using hands-on activities and examples to understand the concepts and topics being discussed
	Individually then Group	Learning concepts at the individual level first by trying to understand, then share at the group level to compare understating and consider different points of view.
	Self Directed (Research/reading)	Take responsibility for the learning process. It involves doing individual research, reading textbooks, using internet.
	Pay attention in Class / Taking good notes	Students following traditional lecture rules, taking notes and following instructor information
	Ask Peers	Using peers to collaborate and discuss concepts and topics in order to create collaborative learning.
	Ask good questions	Ask thoughtful questions to go beyond the information found in class or books. Attend office hours and engage with instructors and TA's by asking follow-up questions

	Teaching	Learning by teaching the concepts to other peers
	Out of the classroom	Engage with out-of-the classroom learning experiences like review sessions, study groups, conferences, and internships
	Practice/ repetition	Practice typical problems several times until the student is able to get the ability to solve them
	Memorization	Memorize facts, concepts, and steps
Why do they learn?	Prestige	Being recognized by others as someone good in the major
	Curiosity or interest	Personal curiosity or interest in a specific topic, subject, or class.
	Good Grade	Perception that learning is related to obtaining a good grade.
	Need to know for future job	Reason to learn in order to know what is required to perform correctly and have the knowledge in order to obtain and retain a desired job.
	Enjoy class/instructor passion	Reason to learn for being in an engaging safe learning environment. Reason to learn because of the impact that a passionate instructor that cares about the students.
How do they use it? Implementation as a professional	Transfer of knowledge	Using classes to learn the professional and technical skills desired in the future job
	Professional skills	Using faculty/student interactions, teamwork, and projects, to understand how to develop a professional network
	Problem-solving	Learn problem solving processes in different class to be able to adapt the skills to different contexts
	Teamwork	Using teamwork experiences in class to know how to collaborate in professional settings

Finally, data were integrated and interpreted (Robson & McCartan, 2016) so that we were able to identify the patterns in the data to describe how students understand their engineering disciplinary culture. The connection between themes can be seen in Figure 2 where we present a visual representation of the story that emerged from the data analysis. Students' responses provided with different themes that describe the culture of the discipline. For them, disciplinary culture needs to be explained in terms of what they think is valued in the discipline, the way that they are taught, the way they learn, the reason why they learn, the way they will use what they learn in the workplace, and the reason why they selected their major. The results section includes detailed information about the interpretation of the findings.

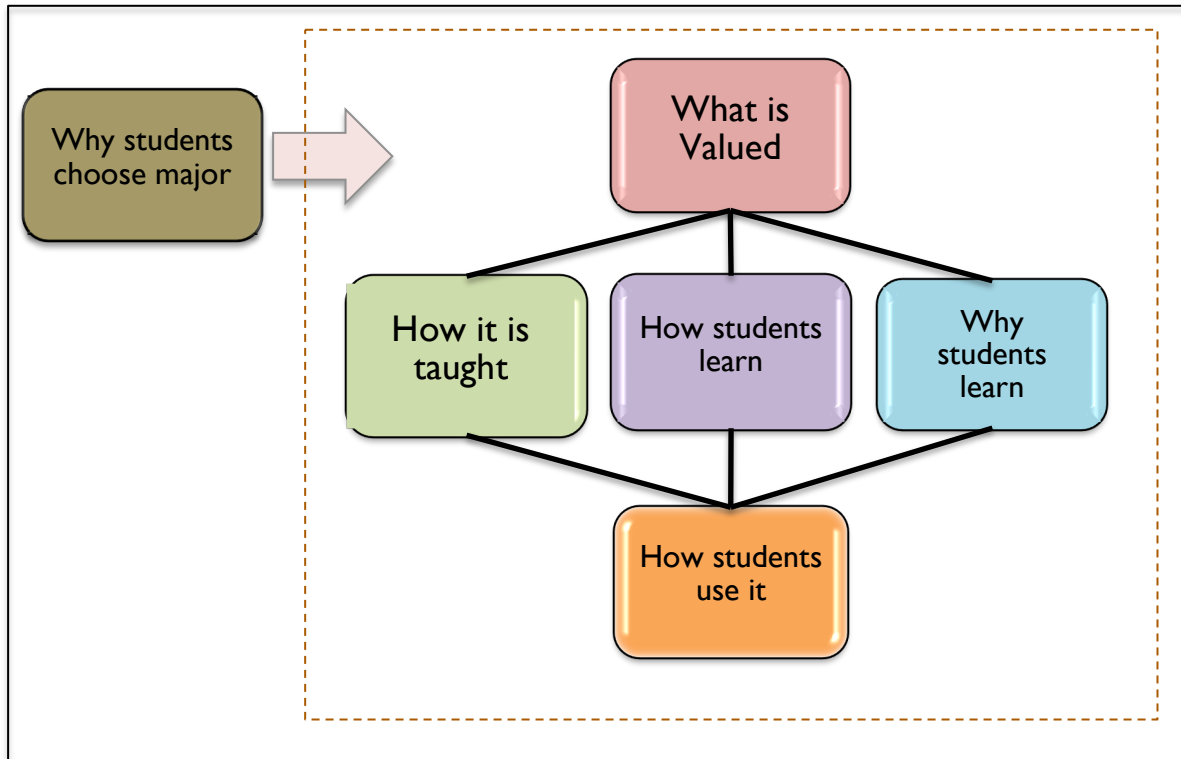


Figure 2. Themes network.

5.5. Findings

Investigating students' cultural perceptions of their discipline in four different majors helped identify the way students form their worldview and perceptions about their academic field. Analysis of the collected data revealed the various ways in which students perceive the culture of the discipline regarding what is valued in the major, how it is taught (teaching process), how they learn it (learning process), why they learn it, and how they believe are going to use it in their professional career. In addition, data revealed information about why the students selected their major that in most of the cases was associated with what they believe are the major's values.

5.5.1. What is valued

Students from each major had different perceptions regarding what is valued in the

major. However, a common characteristic among students in engineering was the importance of solving problems correctly. Students in both ISE and ECE emphasized how important it is to be able to solve problems and have the right answer to become a good engineer. However, there are differences in how the students perceive the reason why problem solving is valued; for example, two students comment about it:

“...it’s like, you know, you need to be able to solve problems, I think that is crucial. If you know how to solve problems and you always get it right, people will recognize you, your professors will recognize you, I think that is what gets doors open here” (ISE#3)

“In ECE it’s all about getting the right answer, you need to become good at learning whatever it takes to get the right answer, if you don’t get the right answer you don’t get a good grade. If you want to be someone in this field, you need the grades and the skills, and solving difficult problems is key for both” (ECE#5)

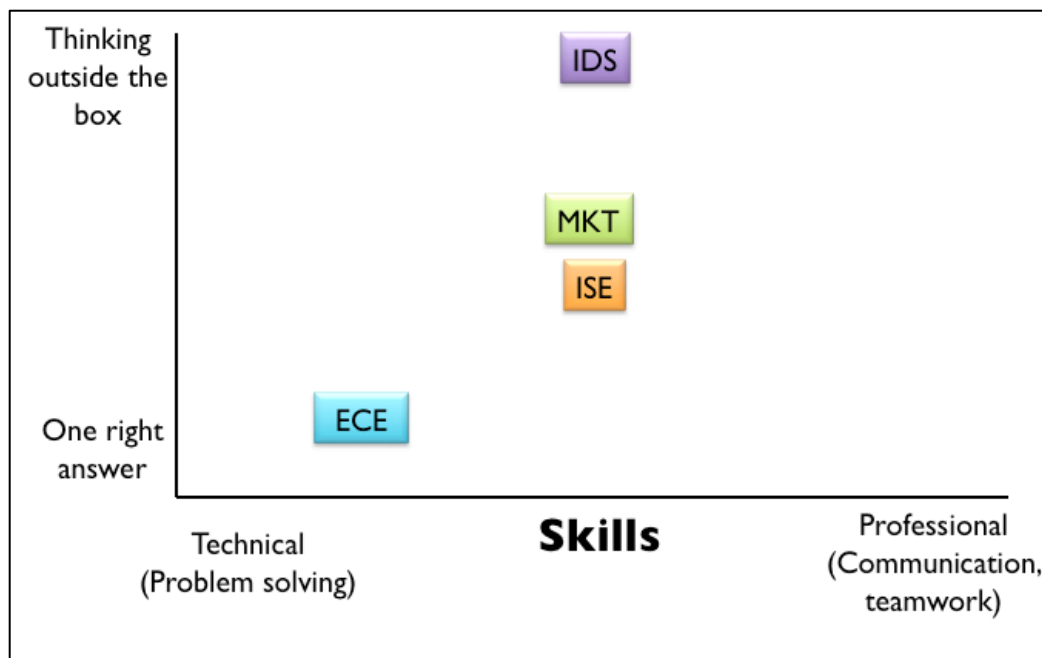


Figure 3. Student perceptions of what the disciplines value

In Figure 3, there is a visual representation of the four disciplines. The figure is not a scale that represents any numerical index, rather is a comparison of each discipline in

regards to the some of the aspects and the skills that they perceived are valued in the profession.

In contrast, for industrial design students, it is not about the final result or the right answer, they value the process the most. For them, right or wrong answers are not important in their field. Since design is an ongoing process that continuously improves, the value is focused on the process itself, not in the outcome. A student commented on it:

“That's tough because our major is very conceptual and it's design, but there's really not a right or wrong answer. It's up to interpretation. Basically, whether your..., because we're designing products, so whether your design is good or not, is not really the point. The point is to show your process and how you thought about it, whether or not it came out successful or not in one person's eyes versus the other. It doesn't really matter. The thought process that you developed designing it, that's what matters, everything is about the process and what you learn from the process.” (IDS#2)

In marketing, students recognize the value of being able to solve a problem, but despite the fact that they recognize that there are right and wrong answers, the focus in this field is on how to find the gray areas between the right and the wrong answer and improve it to make it better.

“...one of the most important things in a marketer is to solve a problem in terms of... like a marketing pitch, I wouldn't say there's necessarily a right or wrong answer. I think there's a better answer and a worse answer, it is very important that we recognize how to make a wrong answer better, for us the secret is on finding improvement areas for what can be perceived as a problem.” (MKT#2).

As expected, industrial design students say that their major values creative and critical thinking the most. They believe in the importance of thinking outside the box, and also the ability to provide and receive critical feedback. IDS students consider that one of the things the major values the most is the ability to provide innovative solutions and avoid

traditional thinking. Similarly, Marketing students consider that creative thinking is very important in their field, especially in the way strategic communication is conducted. They also consider that in their field traditional practices are not valued nor expected. So, similarly, MKT students perceive the value in creativity. They consider that creativity is key in strategic communication, and they believe it is a skill every marketer should have.

“We all know it doesn't matter as long as you are developing your creative thinking. Of course you want to pass but it doesn't matter what score they gave you. As long as you are improving your thinking process on how to approach design, and how to improve your creativity, you are becoming a great industrial designer, and also you will have pieces that you can put in your portfolio and be proud of.”
(IDS#5)

However, less expectedly, engineering students didn't mention creative thinking as something they believe is important in engineering. This was not expected because of the emphasis that industry and engineering schools have put on creative thinking as one of the most important skills engineers should have.

Among all students, except for ECE students, there was agreement on the value of collaboration, teamwork, and developing and maintaining professional relationships and a professional network. ISE students consider this to be very important in their field. They also believe they are recognized and differentiated from other engineering disciplines by their focus on people and their ability to effectively collaborate with others. One student commented on ISE's value for people and collaboration:

“...because in the real world, especially in engineering, you're never going to be doing problems on your own, so that's why our field is important, we bring other engineering disciplines together effectively. In the real world if your company doesn't perform and you're in a group that worked on it, they're not going to grade everyone individually, you need to make it happen, understand others' perceptions, and make the most out of it, engineering without the ability of collaborate and understand people can't exist.” (ISE#1)

For IDS although their work is conducted individually most of the time, they prioritize learning how to interact with others. They perceive that effective design needs to consider diverse opinions. Therefore, interactions with peers and experts are key. They also think that for the major, providing and receiving constructive feedback from peers and professors is part of the value of interactions and collaboration.

“Yeah, because during those pin-ups, students and then the professors will give feedback, like, "Oh maybe think about this in a different way," or "Maybe that's not the right way to pursue it." Sometimes feedback is really hard, but you don't take it personally, you are willing to change. Yeah, it's good to change your mindset because that shows that you're thinking about products and the whole project in a different way, you are expanding your own perceptions to consider what matters to others, which is ultimately what you want to do. It's fine to change ideas and change your route, I think that's one of the most important things of being a designer, listen to others, talk to others, provide feedback, interact and work with other perceptions.” (IDS#6)

Marketing students consider that their field values their ability to help other fields to communicate effectively, and their major also values teamwork. They understand the importance of effective teamwork early in their careers because every class has team projects that require a lot of interaction and collaboration as well as being able to communicate their outcomes effectively. They consider that one of the things the profession values is the ability to understand other disciplines' languages, and translate so everyone can understand.

On the other hand, ECE students not only don't value collaboration and teamwork, but they all agree that working with others can be detrimental to their own success. They believe the field values individual results, and the effective achievement of deadlines; therefore interaction with others can only lead to wasting valuable resources like time.

“We prefer to work alone because you're not distracted. What happens, when you're working in a group and the other person is doing something and what if he did was wrong? You based all your work... was based on his work and all your work is wrong too. If you want something to be done right, you will need to do it by yourself. Also, in teams we always have bad experiences with people not pulling their weight, [pause] actually we hate working in groups. It usually requires the double of work than to do it on your own.”

Engineering students from both majors agreed that engineering values accreditation of engineering programs, ethics, and understanding how things work. The other two majors did not consider these aspects. However, industrial design values gender balance, and marketing values strategic communication, aspects also not considered by the other majors.

Students think that engineering and industrial design both value a balance between technical knowledge and professional skills. They understand the importance in both disciplines to acquire the technical analytical skills specific to their field, but at the same time have professional skills like leadership, communication, and teamwork, and be able to understand the balance needed between both in different contexts. Two students comment in that regard:

“... like engineering, we have a great springboard or foundation to have because it gives you the problem-solving skills but also the leadership skills that you might need in a later career. We need to know how to build the bridge good enough that it doesn't fall but we also need how to be effective directing our team that will be building it, both things go hand to hand in our field.” (ISE#4)

“I really think industrial design has the perfect balance. I have always been very creative, and, at the same time, I am very analytical, so I knew I didn't want to go to art school because it was a little too abstract and there wasn't enough concrete problem solving. I really think the most important thing in industrial design it's to balance between the creative work, but then also analytical problem solving skills, you create unique designs but that solve real people problems.” (IDS#1)

It was evident from the interview data that students in every major perceived that one thing valued in the major is the ability to apply knowledge learned in the classroom in

different contexts and situations, or in what they call “real world examples.”

Regarding how it is taught, and how they learn it, figures 4 and 5 provide a visual representation of the four disciplines regarding teaching and learning, and how some process that describes the learning environment like collaboration and clear rules are perceived. The figures will be explained in detail in the following sections.

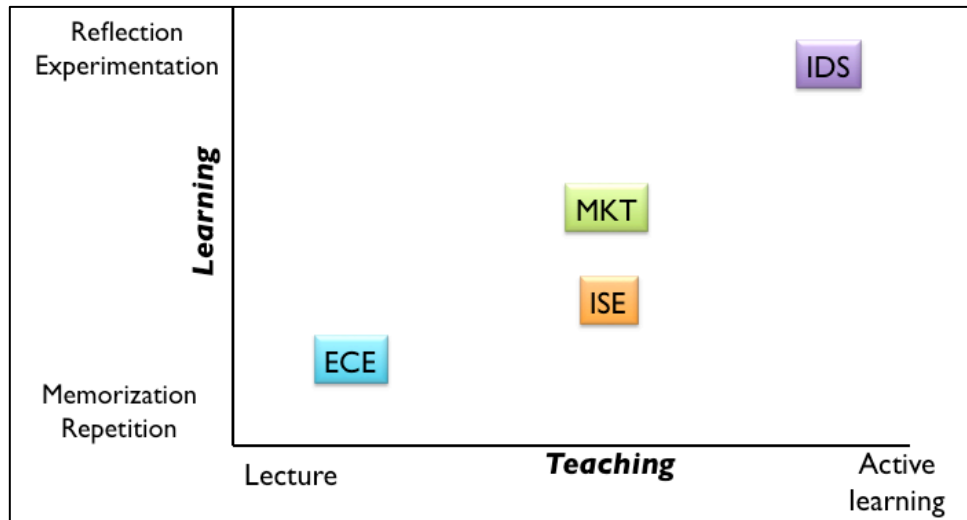


Figure 4. Perceptions of teaching and learning

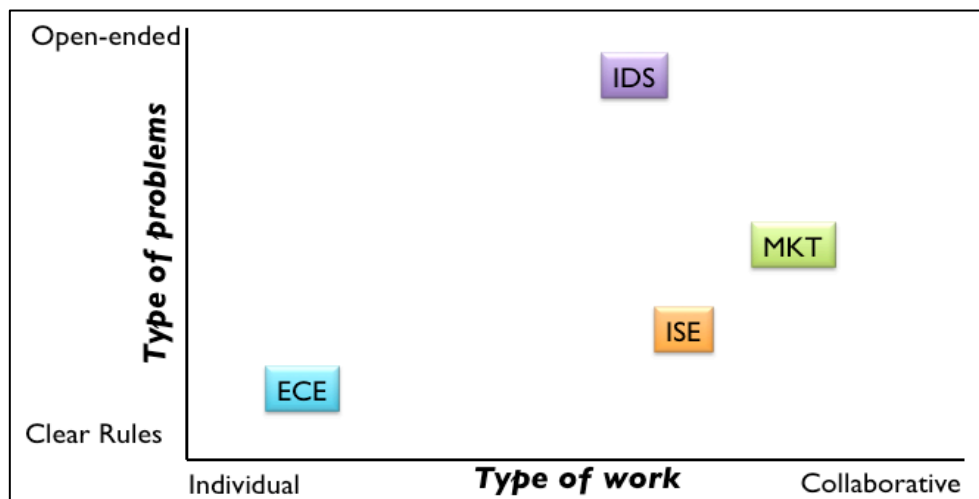


Figure 5. Learning environment characteristics

5.5.2. Teaching process – How it is taught

Students expressed the importance of understanding teaching strategies in their majors as part of the disciplinary culture. There were several aspects of how it is typically taught in the discipline that were discussed by the students.

One common explanation the students provided was regarding the preferred instructional method of the instructors in the major. In the case of ECE students, there is a perception that the tendency is toward traditional lecture, limited participation, and very structured and clear rules. One interesting aspect regarding participation is that students in the major affirm that instructors are approachable; however, when asked when they talked to them, the majority said that talking to professors was not typical of the major.

“I guess [pause] I know that [long pause] I'm not sure why to be honest, I think is just the way our major is, no one have told us you are not supposed to talk to your professor, actually every professor has office hours and say that we can go and talk to them if we have questions, but it just doesn't happen that way. I think in my first semester in ECE I went and talk to one of my professors and ask for feedback on homework and I felt he was really upset; he was like what are you doing here? So for me I think is like the rule, you go sit in your classes don't speak try to get the most out of the class, and figure the rest out by yourself, that's how lecture work right?” (ECE#5)

Industrial design students, in contrast, perceive that in the discipline lecture and traditional teaching practices are avoided. The perception is that the major focuses on discussion-based gatherings where the students and the instructors spend a lot of time together working on-site. According to the students, in this field participation is not only encouraged but expected at all times, and there are no clear rules. In the case of MKT and ISE, students perceive the disciplines as the midpoint between ECE and IDS, having some lectures, but also with a high focus on active learning, discussion, and participation. Students consider that ISE has more clear rules and structure than MKT, which is

considered to be in the other part of the spectra.

ISE students affirm that participation in class is encouraged. They explain that professors will create an atmosphere where students feel the need to participate and it's not only encouraged but also expected.

“She would start early in the semester by asking you questions, but then people were willing to ask questions. If it got a little bit noisy, she would stop and she would make sure that everyone settled down. I think at the beginning you feel a little uncomfortable, but then you get used to and at the end was great, you feel like talking in class is part of how you are supposed to learn” (ISE#2)

Another similar aspect of teaching in ISE and MKT is regarding assignments. In both fields students explained that there is a culture of having a mix between individual and group work, and a good balance between tests, homeworks, presentations, and projects. Also, in this case again IDS and ECE represent two opposite poles. In both majors most of the work is done individually, but participants' perceptions is that in ECE work constitutes tests and homework, while in IDS tests are not typical; instead work is done with two or three large projects through the semester.

One thing that students in every major but IDS perceived as a common thing is the importance of having clear rules. Students from engineering and marketing prefer to always have clear rules, deadlines, and a lot of structure, and they believe it is important to be able to operate correctly and effectively in the field. On the other hand, students from industrial design consider that in order to promote innovation and creative thinking, the major has a culture of using open-ended problems where students are required to have critical thinking as well to be able to achieve the goal of the project.

“If you prefer clear instructions in my major then you are not gonna be in my major [laughs]. Actually, we have people that have dropped out after the first year for that reason. For us, like, design, it is very conceptual and complex, and there is really no right or wrong answer.

When it is open-ended, you have a lot of freedom to really explore new areas and hypothetical, "What if this product was this way?" Something that no one has ever seen before. It may not work or function but you are thinking about it in a whole new way and it is sort of open-ended and loose. Yeah, it may spark new ideas. Yeah, it may not work but look at the direction it could go. Maybe the technology is not there yet but maybe in 10 years or so. What I thought of could actually sort of be practical and come into effect. Problem-based is part of our curriculum, and I think that is what gives us our critical thinking." (IDS#4)

Another aspect on how classes are taught is the motivation to work in teams and team dynamics in the majors. In ECE, students believe that professors don't emphasize teamwork as something important. As mentioned before, they believe working in teams can be a problem most of the time. In ISE there is more emphasis on promoting teamwork, and in most junior and senior classes students say that they will be required to work in teams with the goal of getting experience to what the professional work is like. In general in engineering, the students demonstrated a similar understanding of team dynamics. For them, working in teams mean dividing up the tasks required to complete the project, working individually on the task, and then putting the work together at the end before submitting it or presenting it. During the process, there are some check-in meetings, and students exchange some communication, but they can work for the majority of the time independently.

Marketing students' perceptions is that the major also promotes teamwork in most of their classes. Students learn how to interact with each other and team dynamics have a balance between individual work and work that requires the attention and effort of the entire team. Meetings and communication are frequent, especially using social media like Facebook.

In IDS teamwork happens with relative frequency and students think that it is necessary when individual work cannot get the expected results. Team dynamics in a

project is based on collaboration, and integration of the different skills that every student can bring. Beyond team projects, the students consider that in general, in the field collaboration is motivated at every level, in classes and outside the classroom.

“It’s our culture [long pause], a lot of architecture schools make the students to be very competitive against each other, even though they are in a very collaborative space, they end up fighting again each other all the time, but at here I don’t know how they do it, but they have created this cool culture that everyone is helping each other every time, it’s a big deal, to collaborate with other students, and take seriously other students problems as if those were yours. It’s a really positive space, particularly in ID.” (IDS#2)

One of the problems students recognize in all the majors regarding teamwork is social loafing. Students consider that it is very common that at least one member of the team will not contribute with the team performance expecting for others to do his/her job. Students believe that this problem is minimized when they have the opportunity to evaluate their peers.

5.5.3. Learning process – How it is learned

One of the most differential characteristics of the engineering disciplinary culture compared to other majors is the way students learn. Engineering students believe learning happens by repetition and memorization. They value examples of problems in class, similarity between assignments and tests, availability of teaching assistants (TA) that help them practice problems, and instructors to answer questions. Learning in engineering is an individual process that at some point has group interactions. Usually, students begin individually to learn a concept, and after practicing several times, go to the group looking for confirmation on the way they solve a problem or alternatives solutions to it. An important part of this process is based on students’ ability to attend classes and pay attention, and take good notes.

“Definitely by doing examples over and over again until I feel confident in the concept. I memorize what the concept is, check back my notes, maybe read more on it, but at the end is all about how many times you repeat different examples.” (ISE#6)

Another part of the learning process in engineering is the use and application of industry examples. Therefore, the use of hands-on activities where students can visualize the concepts and principles is very important. Students feel that when they are able to see examples of how the concepts apply in the professional environment, they can understand it better. However, in most of the cases this does not happen in the classroom; therefore, they value out-of-the-classroom experiences like attending office hours, meeting with TA’s, and attending engineering design competitions, conferences, students’ engineering societies meetings, and recruitment fairs. They also value projects that involve hands-on activities like designing something.

For marketing, students believe that learning comes more from interactions with instructors than from memorization. Although students understand the value of learning the concepts first, they believe that the most important learning process comes from discussions and interactions with the instructors.

“...like I know that if I don’t learn what consumer behavior is first, I won’t be able to understand it or talk about it. But when I actually learn what it means is when you have your instructor very motivated about it showing you a product and having the whole class debating on why a type of consumer will prefer the product, that’s when learning happens, those conversations you never forget, when the test comes you already know what to answer.”

For industrial design students, learning is an ongoing process of reflecting. It includes a lot of hands-on activities that require self-directed learning, and a lot of reflection to be able to obtain the expected results. Again, in industrial design the focus is on the process rather than in the outcome. Despite the process of reflection being

individual, students in industrial design consider that learning comes also from the constant interaction and collaboration with peers and instructors.

“I think [pause], It's [long pause], at the end of every semester we put together a portfolio about the things that we do... seeing what I have been doing for three years, you can really see your improvement every semester, because it is a skill, is not knowledge based like engineering or English, or anything like that, is really developing the skills to improve your own work, and it is through a process of reflecting on the things you do and why you do it that you get the skills. Then seeing something I did 3 years ago that in my opinion now is terrible, and looking at something that I just did is [pause] is actually really really interesting to see how far you have gone in just a couple of years. Probably in one year that work will be bad, that's the point, you never stop learning and improving, it's never perfect you just deal with that” (IDS#1)

Students from all the majors agreed on two things. One is that a very important part of the learning process refers to how well they can explain the concepts or topics to their peers. They mentioned how important is the ability to teach others as part of confirmation on their understanding.

The second one is in the importance of asking good questions. They all believe that by asking deep well elaborated questions, they are able to go beyond class materials and the theory provided to them. Asking good questions can be a self-reflecting process that helps the students advance in their self-directed learning, as well as a collaborative process where students ask meaningful questions to their peers or their instructors obtaining valuable information that enriches their learning.

“Then, also, just asking a lot of questions. I feel like whenever I learn something new, I just want to make sure I know every aspect of what it, asking questions gets you there if you really want to learn it” (ISE#2); “...by asking good questions you are able to make your professor tells you the special information that they omit otherwise.” (ECE#2); “If you go to office hours you need to have good questions to ask, it's the only way you get a benefit for your learning from those moments.” (MKT#1); “...and you know you get there when you sit by yourself and

ask really deep questions about what you are doing and reflect on it.”
(IDS#5)

5.5.4. Why they learn it

Despite the similarities between students’ learning process in some majors, the reasons why students learn something varies across majors. In ECE students are motivated for several reasons but the most important for most of the students is to get a good grade.

“...actually, if you do it all because you get a good grade, and you get good at knowing what to do to get the grade, even if you don’t like it. Yeah, I would say it’s not so much about what you learn, it’s about how you understand what the professor wants so you can get an A.”
(ECE#6)

For ECE students, another reason to learn is to get recognition. For them, it is very important to be recognized as a person that is able to master a specific topic or concept. It is very common to want to learn programming to be recognized as a good programmer. This is also shared for ISE students who think that it is important to demonstrate that engineers have knowledge. Recognition and prestige from peers and the community is a big motivator for learning among engineering students.

In addition, ISE students have a motivation to learn because they believe they will need the information when they go into the job market. For them, it is very important to have the knowledge required by industry.

Part of this success in industry is also related to the development of professional networks, therefore, they want to be recognized as good students to start developing their network with their professors’ acquaintances.

“You want to make sure that you really are grabbing those concepts. Because, you are going to the job market soon, and there you are not going to fool anyone, either you know or you don’t, what will happen when you get a project assigned, they expect you to know your stuff. That’s the biggest reason why I put effort on learning the material in my classes.” (ISE#3)

Industrial design students are intrinsically motivated to learn. They perceive their major is a field where learning is part of their professional identity, and it's a process that doesn't stop.

For all students in every major a an important reason to learn is to understand how things work, to be curious and engaged with things related to their field is key to become a professional. This curiosity motivates students to want to learn more about a topic, a specific theory or a class, and put the required effort to do it.

5.5.5. How it is used – knowledge transfer

Industrial design and marketing students are clear on the importance of being able to adapt what they learn into different contexts. For them, the transfer of the knowledge obtained in the classroom to their professional workplace is essential; therefore, they try to be aware of what they learn, how to apply it, and the possible implications of doing it. They recognize the importance of problem-based learning and creativity when developing these skills.

For engineering students, the transfer of knowledge into the profession is still a challenge. Part of the problem is the high focus on good grades, and getting the right answer, that limits the adaptability and contextualization of knowledge in different contexts and unexpected situations. Some students that have had internships were able to recognize the importance of being able to translate what they learn in engineering schools into the workplace. They realize that the success in the internship depended upon skills that they haven't considered during their academic program, and that the things that they practiced the most were irrelevant when in the workplace.

“I feel like the motivations are entirely different and... so I love the

internships you have people who are above you who are invested in helping you to learn what you need to know to succeed where I feel like here you're given a ton of information, and the teachers and the TA's, you get so many times that they have to say "Oh I can't really tell you that because that would give away the answer." Where when you're working somewhere everybody wants to tell you the answer because it's gonna help you get to the end result faster, however you need to know the basics, if you don't know what they are talking about you can't use it. I've certainly worked with people in internships where we've been in the same major to the same. Point were presented a problem in a work environment and I feel like I know how to do it easy and they're like: I feel like I've learned that somewhere but I can't really remember. I'll have to go figure it out." (ISE#1)

5.5.6. Why students choose the major

There are several reasons why students select their major based on the students' perceptions. The reasons come from what students' believed is valued in the field, how teaching and learning processes matched their own processes, and how their own skills and competencies at the moment were suitable for what they taught was required to success in the field. One common thing in engineering students is the influence that a role model like a parent or a mentor had when making the decision. Usually, they were pushed to consider engineering because the role model saw very good mathematical skills in the student.

In the case of marketing, several students explained that they selected the major based on financial reasons because marketing jobs are considered to offer high salaries. This is shared by some engineering students in ECE that selected that particular engineering program because of financial reasons.

In the case of industrial design, students were looking for a major that had a balance between the arts, and a technical profession like engineering, and they consider that the major had the adequate balance.

It was also possible to see the connection between the reasons for students selecting a major, and what students perceive as valuable in the major. For example, ISE students selected the major because they considered that it was the major that better developed professional skills, and was more focused on people.

“I can't sit behind a computer all day. I can't crunch numbers all day. I have in some of the classes that I've had to take as a pre-req to graduate, I guess, like dynamics and statics. I got through them but I didn't really like them. I think that just sort of validated that I needed to work with people in some way” (ISE#4)

Similarly, ECE students joined the major for their interest in obtaining programming skills that allowed them to build their career and to work individually, something that is valued in the profession.

In the case of IDS, students selected the major to be able to explore their creativity, and analytical skills at the same time. As mentioned before, they believed the major offers a good balance between the freedom to think outside the box and make mistakes, and the rigor of understanding technical concepts to be able to design something that solves a problem.

5.6. Discussion

The findings presented earlier identified how students define their disciplinary culture. In this study, we are particularly interested in engineering, so we use engineering as the reference to discuss our findings and try to describe the engineering disciplinary culture from the perspective of the students. Table 15 provides the big picture of the findings by discipline.

Table 15.
Cultural characteristics of majors studied

Cultural aspect	ECE	ISE	IDS	MKT
Valued	Problem solving focus on right answer. Focus on technical skills. How things work. Ethics. Accreditation.	Focus on people. Problem solving. Collaboration. Balance (technical knowledge/professional skills). How things work. Ethics. Accreditation	Creativity. Critical thinking. Problem solving focus on the process. Balance (technical knowledge/professional skills). Collaboration. Feedback.	Communication Problem solving. Creativity. Collaboration.
Teaching process	Lecture Limited participation Structure and clear rules Individual emphasis	Lecture Active learning Participation Structure and clear rules Teamwork	Active learning Discussion-based learning Problem-based learning Feedback High participation Open-ended	Lecture Active learning Participation Discussion-based learning Teamwork Structure and clear rules
Learning process	Repetition Memorization Use of industry examples Asking good questions Hands-on Informal learning Teach to peers	Repetition Use of industry examples Asking good questions Hands-on Interactions with others Informal learning Contextualization of problems Teach to peers	Reflecting Ongoing process Hands-on Self-directed learning Interactions with others Teach to peers Asking good questions	Conceptual learning Interactions with others Asking questions Use of industry examples Contextualization of problems Teach to peers Asking good questions
Why they learn	Get a good grade Recognition Curiosity Understand how things work	Recognition Need to know for job Curiosity How things work	Intrinsic motivation Curiosity Understand how things work	Curiosity Understand how things work
Knowledge transfer	Limited by focus on right answer, but recognized when doing internships	Limited by focus on right answer, but recognized when doing internships	Problem-based learning Creativity	Problem-based learning Creativity
Why they select major	Good in math Influence of role model Individual work Programming skills Solve problems	Influence of role model Focus on people Professional skills Solve problems	Balance between art and technical profession Solve problems	Financial reasons Influence of role model

Results describe how students understand their disciplinary culture in two different engineering majors and two non-engineering majors. These perceptions can be also contrasted with the theoretical frameworks used in this study. Regarding Hofstede (1993) theory, findings demonstrated patterns in students perspectives of academic fields that relate to Hofstede's dimensions. There are several differences in the students' perceptions of the disciplinary culture in term of Hofstede's dimensions that were not caught in the results from the survey in the quantitative study. Students in IDS and MKT tend to be the less individualistic. In addition, there are differences between students' perceptions in ISE and ECE, ISE being more collective and ECE being the most individualistic discipline of the study. These differences were not caught by the quantitative study previously conducted where we didn't find significant differences between the two engineering majors. Similarly, regarding power distance, students' perceptions in IDS and MKT are that the disciplines have less power distance. Students' feel like their professors are approachable and the authority dynamics motivate their engagement and participation. This is not the same situation in engineering, where students perceive that their professors' authority is a barrier to becoming engaged and actively participate in the classroom. In regards to uncertainty avoidance, there are also several differences between the engineering majors that were not perceived in the quantitative study. Students in ISE are more comfortable than ECE students with uncertainty, ambiguity, and taking risks.

In addition, it was possible to compare the students' perceptions of the disciplinary culture with the Nulty and Barrett (1996) and Bradbeer (1999) frameworks. Figure 6 is a visual representation of how the disciplines are classified in regarding their framework. In their framework, Nulty and Barret, and Bradbeer do not differentiate between engineering

majors. They classify the engineering discipline as being in the concrete/hard – active/applied quadrant. The authors consider engineering to be a discipline where knowledge is concrete rather than abstract, and the way they approach knowledge is from active application. This was also confirmed by the findings in our study. However, there are some differences between ISE and ESE based on the findings. ISE students' perceptions are that the discipline values less concrete knowledge than ECE. Similarly ISE form of knowledge is less active/applied than ECE. ISE students value some reflection. Findings regarding students' perceptions of IDS show the discipline on the intersection of the four quadrants. The discipline has value for concrete/hard knowledge and abstract/soft as well. This is represented by the balance between the value of technical skills and professional skills. According to the students the discipline requires to have abstract knowledge to be able to provide creative designs, but at the same time concrete knowledge so the designs meet the technical requirements to work functionally. In addition, they approach knowledge with a balance of actively applied experimentation by actually developing the things that they design, but with a lot of pure reflection, since they consider design an ongoing process based on how they approach feedback, and reflect on previous work.

Overall, the findings provide information that helps us to better understand the engineering disciplinary culture. Engineering continues being a traditional discipline that values technical skills and the ability to solve problems and obtain the right answer. Industrial and systems engineering seems to be more inclined to also have a focus on people and the importance of professional skills. However, the major in general is perceived as having the same culture that has generated some criticism in the last decades. Students receive information from lectures by instructors who don't encourage participation. The use of technology is limited to using presentation slides and an online

academic managing system. Learning comes from memorization and repetition of typical problems that will then be evaluated on a test. Interactions are not promoted, and individual work is perceived as more important than teamwork. Even when students have to work in teams, the concept of teamwork is a division of tasks to be developed individual, instead of mutual collaboration where everyone provides a different perspective and synergy is encountered by the sum of individual efforts cohesively.

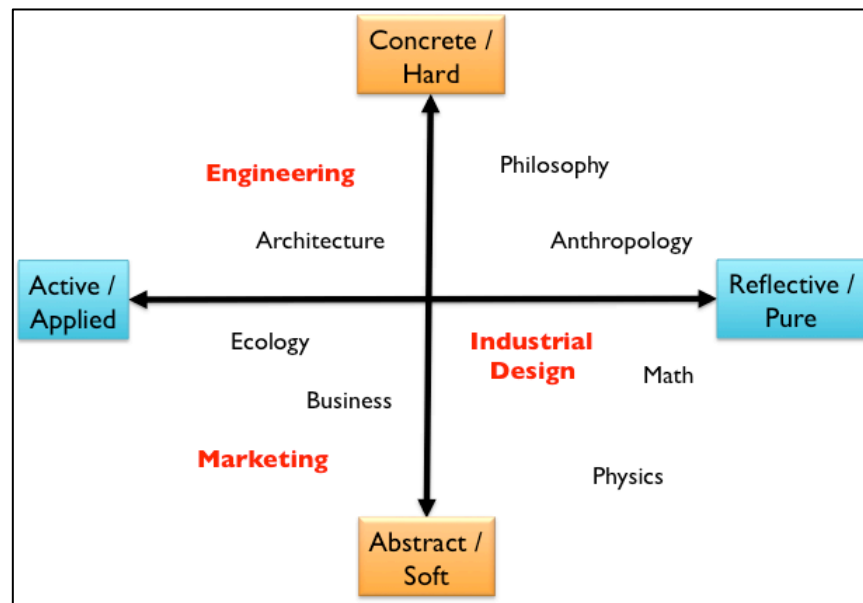


Figure 6. Disciplines classification. Adapted from Bradbeer (1999) and Nulty and Barrett (1996)

Although engineering students recognize the value of hands-on activities, the contextualization of knowledge with industry examples, and the reflection process of asking good questions, there are not enough places in engineering classrooms where these things are happening. Students understand what is required to be a good engineer, and what is expected from them in industry; however, they believe that engineering schools are not providing all the resources and instructions for them to do so. Furthermore, students who do internships and come back to continue with their degrees recognize that the engineering

disciplinary culture is not up to date with industry expectations and requirements.

Findings also provided information about other majors' cultural characteristics that are doing interesting things that we can copy in engineering. For example, we need to promote more collaborative environments (similar to industrial design) where students feel comfortable working with others, learning how to provide and receive constructive feedback, and feel more motivated to participate in class discussions and engage with professors and peers. As a consequence, engineering students' ability to collaborate and work with others will be improved, a desired industry skill.

In addition, it would be important to promote more active, problem-based, and discussion-based learning in engineering classrooms. If students get familiar with open-ended problems, and with the need to contextualize their problem solving skills in different scenarios outside of tests or homework, students can potentially improve their critical thinking, their creativity, and their ability to understand diverse points of view. This will also help with taking out the emphasis on one right answer, and rather focus more on the process using self-reflection.

5.7. Implications

The findings provide implications for how researchers might understand engineering disciplinary culture in term of the cultural characteristics we describe in this study. The study also has implications for practice, regarding how to design better learning environments in engineering and promote more collaboration. Lastly, we provide some implications for policy.

Considering that students have a perception of engineering disciplinary culture in terms of what is valued, how it is taught, how and why they learn, how they use what they learn, and what motivates them to get into engineering, the information from this study can

provide a better understanding of how students perceive the field. As such, our findings have several implications for practice in order to inform what the strengths of engineering programs are and the barriers that students perceive are not allowing differences in how the culture of the profession is perceived.

In practice, engineering instructors can use this information to better understand how students perceive their classrooms, and start thinking about what changes can be done in their pedagogies. Becoming more approachable, engaging students, promoting more participation in class, developing more open-ended problems, and hands-on activities, are some of the things that engineering students consider necessary and feel are lacking.

In addition, the information can provide support to freshmen engineering students when making decisions on their engineering major. If they understand how students perceive they are taught, they learn, why they learn, and how they use what they learn, freshmen will be likely to make a more informed decision in what they want during their time in college.

This study provides researchers in engineering education with information to advance the understanding of a complex construct like culture, by the use of different theoretical frameworks from education, and business and sociology. In this study, we used a very recognized framework to study culture in the business field. However, the framework had limitations to explain cultural differences in an academic context. Therefore, the development of the interview protocol started using Hofstede's model of dimensions of national culture and was complemented by the models of disciplinary differences developed by Nulty and Barrett, and Bradbeer.

The integration of the different theoretical frameworks allowed us to identify cultural disciplinary differences that were not able to capture by using only one of the

models, hence, we can advance the understanding of culture by using this integration. Researchers can use the information provided in this study as a guidance and a motivation to explore theories that have already been developed in other fields and implement them in engineering education.

In addition, this study has implications for policy and administration. Findings suggest a need for the development of more collaborative learning environments in engineering, as well as more spaces where active learning and hands-on activities can be conducted. Administrators should consider this information to create engineering classrooms that allow students and instructors develop a culture of interactions and collaboration, like open spaces instead of traditional lecture halls. This information also can be used in order to make decisions on students' requirements to be admitted or transferred into engineering programs, and selection criteria when engineering faculty are being hired and trained.

Similarly, findings can help administrators evaluate different aspects of the engineering program like whether prerequisites and co-requisites in engineering curriculum are making sense for the engineering majors, and whether current admission and transfer criteria are the best methods to admit engineering students that will succeed. Results can also inform on the focus of K-12 outreach programs since it will be easier to find students that will have what the major values.

5.8. Future work

Our specific aim for this study was to better understand students' perceptions of engineering disciplinary culture and how it compares to other majors. As such, it was not our intention to generalize our findings to describe each engineering major. However, a potential future direction for this work would be to develop a quantitative survey that is

able to measure the dimensions of culture found in this study in order to study engineering majors longitudinally to see the cultural differences between engineering majors, as well as how students' perceptions evolve over time.

In addition, we analyzed in this study engineering disciplinary culture from the perspective of students. It would be interesting to conduct a similar study and analyze faculty members' perceptions of the dimensions explained in this study to learn how their perceptions compare to the students' perceptions.

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6. Chapter 6. Understanding disciplinary engineering culture

6.1. Introduction

The purpose of this study was to understand engineering disciplinary culture using Hofstede's dimensions of national culture, a very well known cultural theoretical framework in sociology and business. To meet those objectives, the study addressed the following research questions:

RQ1: Can Hofstede's model of dimensions of national cultures be used to explain disciplinary cultural differences?

RQ2: What are the primary categories of critiques of Hofstede's survey instrument?

RQ3: How can these limitations be minimized to make Hofstede's model appropriate for adaptation to an academic setting?

RQ4: How do undergraduate engineering students perceive their disciplinary engineering culture in comparison to students in marketing, and industrial design?

This chapter synthesizes the findings of the three manuscripts that resulted from those research questions. In addition, information on how the findings relate to the theoretical frameworks used to inform the study is presented. Finally, I discuss implications of those findings in terms of engineering education practice and engineering education research. The chapter concludes with a proposal for future work that can be conducted based on the information presented in this study.

6.2. Understanding engineering disciplinary culture

Findings of this study provided information on how students perceive their engineering disciplinary culture. I summarize the findings with respect to the primary research questions in Table 16. More details about the findings are provided throughout this chapter. Based on this study I was able not only to describe engineering disciplinary culture, but to also evaluate to what extent Hofstede's model of dimensions of culture can be used to explain academic disciplines.

Hofstede's model proved to be a valuable framework for measuring culture at the national level; students enrolled in a University in the United States provided responses regarding the dimensions that matched the country scores on those dimensions. Despite not being able to explain disciplinary differences with the model, using the dimensions of individualism, uncertainty avoidance, power distance, and masculinity was valuable for developing an interview protocol that allowed me to understand cultural differences at a level beyond the nation (i.e. the academic discipline).

Results from the overall study allowed me to have a better understanding of how engineering students perceive their disciplinary culture. Engineering students perceive that to operate in their discipline, they need to develop problem-solving skills, an ability to find the right answer, an ability to understand how things work, technical skills, and ethics. In ISE, it is also important to develop people skills. Interactions with peers and instructors in engineering are limited. Participation in class is not encouraged, and despite seeing their professors as approachable, students avoid interactions with them inside and outside the classroom. In ISE, an interaction with peers is promoted with more emphasis; however teamwork is understood as the division of work rather than synergistic collaboration. Learning in engineering comes from receiving information from the instructor during

lecture, practicing typical problems and memorizing the required information. An important part of the process deals with asking good questions, and for ISE students being able to discuss topics with peers. In this section, I describe the findings for each manuscript in more detail.

Table 16.
Summary of findings

Research Question	Data	Findings
RQ1: Can Hofstede's model of dimensions of national cultures be used to explain disciplinary cultural differences?	Quantitative: Survey	<ul style="list-style-type: none"> • Results in dimensions indicated national culture orientation • Engineering students have mid to high scores in individualism • Engineering students have mid to high scores in uncertainty avoidance • Engineering students have mid to high scores in power distance • Engineering students have high scores in masculinity • It is required to explore further Hofstede's model, and disciplinary culture from another perspective
RQ2: What are the primary categories of critiques of Hofstede's survey instrument?	Qualitative: Literature Review	<ul style="list-style-type: none"> • Hofstede's model has received criticism regarding: <ul style="list-style-type: none"> ○ the conceptual basis of his model for measuring culture. ○ methodological issues of internal consistency, replications of the dimensions, validity, and the wording of the dimensions. ○ the incorrect use of his model for something that it was not designed for; e.g., in our case it was not possible to understand disciplinary differences because the model measures national cultural differences. • Hofstede's model has been successfully used in different contexts. In our case we used it as a reference to develop a better data collection strategy that allowed us to better understand engineering disciplinary culture.
RQ3: How can these limitations be minimized to make Hofstede's model appropriate for adaptation to an academic setting?		
RQ4: How do undergraduate engineering students perceive their disciplinary engineering culture in comparison to students in marketing, and industrial design?	Qualitative: Interviews	<ul style="list-style-type: none"> • Disciplinary culture can be explained according to the data by examining how students perceive values of the major, learning processes, teaching processes, reason to learn, use of the information in future career, and reason to select the major. • Engineering disciplinary culture differs from marketing and industrial design in what students perceive in terms of value, how they learn, why they learn, and how they use it. Major differences were found between engineering and industrial design.

6.2.1. Using a version of Hofstede's survey to understand engineering disciplinary culture.

The first manuscript aimed to answer our first research question with a quantitative approach. We used a valid and reliable version of Hofstede's survey developed by Sharma (2010) to evaluate if Hofstede's dimensions could provide a better understanding of engineering disciplinary culture. We confirmed validity and reliability of Hofstede's model with our results. As expected, results from engineering students confirmed that the model measures national culture; scores in Hofstede's dimensions were similar in all the majors studied, and reflected the United States national culture. Results provided information regarding the four dimensions of Hofstede in different engineering majors. The scores for each dimension are

- **Individualism:** Students in engineering had scores around 4.5 (on a 1 to 7 scale) on average on individualism. We were expecting higher scores on this dimension considering that the United States has one of the higher scores of individualism worldwide; however since Sharma's instrument measures individualism as a combination of interdependence and independence the score makes sense. Students in engineering will have a cultural preference for working individually and independently.
- **Power distance:** students' scores in this dimension are in the mid-high level, similar to what the score is in the United States culture. Engineering students according to this dimension may have a tendency to expect the instructor to provide them with all the information and instructions, and to have minimal interaction with faculty members inside and outside the classroom.
- **Uncertainty avoidance:** in this dimension, similar to the United States culture, students are in the mid-high score of avoiding uncertainty. Based on Hofstede's

definition and our interpretation of the findings, we argue that engineering students will have resistance to uncertainty, and will always seek clear rules, closed-end assignments, and no room for surprises.

- **Masculinity:** engineering students, as well as United States as a country have a high score for masculinity. This dimension was one that we didn't explore in detail because of the limitations that the label of the dimension has. However, it is important to understand that engineering students may be driven by competition, rather than collaboration.

Results from this manuscript provided information to improve understanding of how engineering students score regarding Hofstede's dimensions of culture. Despite having some statistically significant differences between electrical and computer engineering and industrial and systems engineering, in general, results map to the United States national culture. Hofstede's framework has limitations in explaining differences in specific engineering majors; however it provided a starting point for developing a model that can measure culture beyond the national level and into a finer grained examination of each major that focuses on the students' perspectives of what they value, how they think, how and how they feel and behave in the discipline.

6.2.2. Reviewing the literature to analyze Hofstede's model

The second manuscript aimed to understand better the application of Hofstede's model to different contexts. We conducted an extensive literature review on Hofstede's framework to identify (i) the main critiques of his theory, and (ii) lessons from successful application of his model to guide our work in the understanding of engineering disciplinary culture. Hofstede's model has received conceptual and methodological critiques. In our

research the main limitation was the use of a model developed to measure culture at the national level, to quantitatively measure culture at the disciplinary level. Nevertheless, Hofstede's model has been successfully used in different contexts. From this manuscript we were able to understand the reasons why Hofstede's model doesn't map to academic disciplinary differences, and how to use his dimensions to inform a qualitative study that allowed us to obtain information about disciplinary cultural differences between two majors in engineering and two other majors.

6.2.3. Understanding students' perceptions of engineering disciplinary culture

The third manuscript aimed to understand disciplinary culture in engineering and how it compares with different disciplines. Data from the interviews provided information about student perceptions of what the disciplines value, teaching processes, learning processes, reason to learn, knowledge transfer, and reason to select the major.

Regarding what the majors value, students perceived that engineering values technical skills while industrial design values professional skills.

Students defined how they perceived teaching and learning in their discipline. In engineering, the main teaching strategy is lecture, with limited participation, while in industrial design, it's all about active learning. Similarly, students in engineering learn by memorization and repetition, while in industrial design they learn by reflecting on the ongoing design process. Collaboration happens as an important part of the learning process for IDS, MKT and ISE; however it is not considered important for ECE.

Students in all the disciplines value hands-on activities, examples where they can apply what they know in different contexts, and asking good questions that can help them

think further in the concepts that they are learning, and at the same time can help the instructors provide with additional information that otherwise would be omitted in class.

Finally, students in engineering recognized the importance of being able to transfer what they learn in the classroom into their professional context after participating in interviews. They recognized that during their time in industry one of the most important things was the ability to contextualize the technical skills they had into different situations and problems, and they believe that engineering schools need to work more on providing collaborative learning environments that promote active learning and creativity when finding solutions to solve problems.

6.3. Engineering disciplinary culture from the perspective of the theoretical frameworks

In this section, I will summarize how the findings of this study tie back to the theoretical frameworks used to guide my research.

6.3.1. Hofstede's dimensions of national culture

Hofstede's framework was developed to measure national culture in terms of behavioral dimensions. The model was designed to evaluate different cultural constructs and define cultural characteristics of a nation based on the responses that individuals belonging to that country provided. Despite the fact that we couldn't use his framework to understand differences in disciplinary culture in engineering majors, we were able to obtain valuable information to inform the engineering education field. I elaborate on each dimension but masculinity on this section. Masculinity was not considered because we have had issues dealing with the labeling of the dimension and this was the dimension that least informed our research design.

6.3.1.1. Individualism. Engineering students tend to be individualistic. They are not encouraged to learn in groups, to interact with peers, and to create collaborative environments. Typical engineering classrooms (lecture halls) actually are designed to minimize collaboration between students. Some courses, especially in ISE, try to promote collaboration by assigning several group projects during the semester/program. However, students understand collaboration by division of work, rather than integration of different skills and perspectives that complement one another. Students' learning in engineering happens at the individual level, they go to peers just to look for confirmation that what they are doing is right, or to try to explain what they know to their peers, which is considered a great learning tool for them. Some engineering disciplines like ECE consider that working with others not only is not important but also can be detrimental to the efficiency and good performance of someone's work. One takeaway from this dimension is that in order to promote teamwork in engineering classrooms it is necessary to create more collaborative physical spaces. Despite that several courses in engineering having requirements to work in groups, and despite several initiatives in engineering majors to promote teamwork in their students, students keep perceiving the culture of the discipline as individualistic. Therefore, just assigning group projects is not enough. Students in industrial design value collaboration and interactions with peers because it is part of their culture since the first year. They also have a space that motivates and forces collaboration. One recommendation for engineering programs would be to try to implement a similar model to industrial design—at least in the first year engineering program- that can promote collaboration and provide with more interactions with peers and faculty members.

6.3.1.2. Power distance. Students in engineering have limited interactions with their instructors, and will accept what they say as the rule. They may have a tendency to expect

the instructor to provide all the information and instructions, and to have minimal interaction with faculty members inside and outside the classroom. In addition, engineering disciplinary culture does not motivate students to challenge those in positions of power (i.e. the professor). One consideration regarding this dimension is in how students in ISE explained the importance of using professors in the department start developing their professional network. They consider that having a professional network is what opens the door to find good engineering jobs. Therefore, it would be beneficial if more interactions between students and faculty members in engineering are promoted.

6.3.1.3. *Uncertainty avoidance.* This dimension is very important for the engineering field, since accepting uncertainty can be necessary for engineers to be able to deal with the constant challenges of designing and solving complex problems in the globalized world. However, engineering students feel uncomfortable with uncertainty. They prefer clear rules, structured courses, and very limited need to think outside the box. It would be beneficial for engineering schools to evaluate the ways industrial design programs are structured and consider re-structuring engineering programs in similar ways in order to promote more critical thinking, creativity, and innovation but not at the expense of technical knowledge.

6.3.2. Teaching and Learning frameworks.

Regarding the frameworks used by Nulty and Barrett (1996) and Bradbeer (1999) on disciplinary differences in teaching and learning, our findings provided information on teaching and learning from the cultural perspective of the students. In their framework, Nulty and Barret, and Bradbeer do not differentiate between engineering majors. They classify the engineering discipline as being in the concrete/hard –active/applied quadrant. The authors consider engineering to be a discipline where knowledge is concrete rather

than abstract, and the way they approach knowledge is from actively application. This was also confirmed by the findings in our study. However, there are some differences between ISE and ESE based on the findings. ISE students' perceptions are that the discipline values less concrete knowledge than ECE. Similarly ISE form of knowledge is less active/applied than ECE. ISE students value some reflection. Findings regarding students' perceptions of IDS show the discipline on the intersection of the four quadrants. The discipline has value for concrete/hard knowledge and abstract/soft as well. This is represented by the balance between the value of technical skills and professional skills. According to the students the discipline requires to have abstract knowledge to be able to provide creative designs, but at the same time concrete knowledge so the designs meet the technical requirements to work functionally. In addition, they approach knowledge with a balance of active applied experimentation by actually developing the things that they design, but with a lot of pure reflection, since they consider design an ongoing process based on how they approach feedback, and reflect on previous work.

Bradbeer (1999) and Nulty and Barrett (1996) categorize marketing as active/applied – abstract/soft. The discipline values abstract knowledge rather than concrete knowledge, and they acquire knowledge actively applying what they learn. Findings from the study also confirm this classification of the Marketing major. Students believe that they learn by active experimentation rather than reflection.

Based on this study, we consider that students perceive engineering as a discipline that values technical skills, problem solving, and ability find correct answers to problems. However, we believe there is also a perceived need in engineering to have more abstract conceptualization, and active experimentation that students in the majors studied consider is necessary—especially to be able to transfer knowledge to the workplace---but is lacking in

engineering schools. Engineers need to be able not only to solve problems but also to understand the complexity of different contexts and the uncertainty of the globalized world. One thing engineering schools can learn from this study is to promote a culture similar to what they do in IDS. Engineers need to balance technical skills with professional skills and an ability to adapt the technical knowledge to respond to complex situations in very different contexts. In addition, IDS promotes a culture of critical thinking and creativity that is desired in engineering students. These skills can help engineers to include diverse points of view in the designs that they create without sacrificing the technical components of design.

6.4. Implications

6.4.1. Implications for Engineering Education Practice

Understanding engineering disciplinary culture from the students' perspectives is a valuable tool to provide faculty members with information that they can share with their students so they understand what the engineering major value since they start in the program. As explained before in this document, this approach may not be the best approach to improve engineering education classrooms but is no doubt a great one, therefore, its relevance and importance can be understood by the several implications that the study has. It is important for faculty members and administrators to understand the dimensions of national culture (U.S.) shared by students. Understanding that the United States culture tends to be individualistic, avoid uncertainty, and accept power distance, can help faculty members shape the way they design their learning environments. Administrators can promote more collaboration, risk taking, problem-based learning, and engaging relationships between faculty members and students. Engineering instructors can use this information to better understand how students perceive their classrooms, and start thinking

about what changes can be done in their pedagogies. Becoming more approachable, engaging students, promoting more participation in class, developing more open-ended problems, and hands-on activities, are some of the things that engineering students consider necessary and feel are lacking.

In addition, the information can provide support to freshmen engineering students when making decisions on their engineering major. If they understand how students perceive they are taught, they learn, why they learn, and how they use what they learn, freshmen will be likely to make a more informed decision in what they want during their time in college.

In addition, this study has implications for policy and administration. Findings suggest a need for the development of more collaborative learning environments in engineering, as well as more spaces where active learning and hands-on activities can be conducted. Administrators should consider this information to create engineering classrooms that allow students and instructors to develop a culture of interactions and collaboration, like open spaces instead of traditional lecture halls. This information also can be used in order to make decisions on students' requirements to be admitted or transferred into engineering programs, and selection criteria when engineering faculty are being hired and trained.

Similarly, findings can help administrators evaluate different aspects of the engineering program like whether prerequisites and co-requisites in engineering curriculum are making sense for the engineering majors, and if current admission and transfer criteria and requirements are necessary to admit engineering students that will succeed. Results can also inform on the focus of K-12 outreach programs since it will be easier to find students that will have what the major value.

6.4.2. Implications for Engineering Education Research

Understanding disciplinary culture in engineering majors may help researchers change the way they understand the phenomenon of engineering culture. This study provides researchers in engineering education with information to advance on the understanding of a complex construct like culture, by the use of different theoretical frameworks from education, and business and sociology.

This study also provides information on the challenges of conducting research and testing a theory developed for other purposes but yet can be valuable to help inform research designs that can capture what the researcher is looking for.

By applying three different theoretical frameworks to understand disciplinary culture, this study can help engineering education researchers develop new ways to measure and identify complex constructs like culture, innovation, design thinking, or critical thinking.

6.5. Future work

The results of this study encourage follow-up studies for further exploration and understanding of disciplinary culture:

- The development of a survey instrument to measure disciplinary culture quantitatively in different academic majors. The survey can be developed using the themes that guided the qualitative manuscript and use the interview protocol questions as the base to develop quantitative questions informed by Hofstede, Nulty and Barrett, and Bradbeed. The instrument will go through a validation process. Data can be collected at a large scale in several types of institutions in order to be able to make inferences about disciplinary culture in different engineering majors. Findings can also provide a better understanding of the differences (or not) between

types of institutions, and identify if variables like gender, age, nationality, or race have an influence on how students perceive their engineering disciplinary culture.

- A longitudinal mixed methods study to collect data quantitatively and qualitatively regarding how students' perceptions of disciplinary culture evolve over time and determine if students perceive their disciplinary culture because they are taught to do it, or if they are selecting their disciplines because of certain cultural characteristics and values they have before coming to college. The study will track students since high school and until they finish their academic program in college. The data will be analyzed to see how students' perceptions change or not over time to determine the influence of the academic program in the students perceptions of the culture in the field.
- Replication of the current research design using faculty members as the participants in order to understand their perspective and compare them with the students perspectives presented in this study. The study will use the same interview protocol developed already and data will be collected qualitatively. The results can be compared to the students' perceptions so we can identify if there are similarities and differences in their perceptions. It can also provide information on why students perceive some of the things that they describe as the culture of the discipline and will provide important implications for practice and policy when contrasting students and faculty members views.

6.6. Concluding remark

I believe that culture is a complex and powerful concept. I have spent most of my academic career in Venezuela trying to understand institutional culture in my hometown University. Yet, after 8 years of research I couldn't find the right answer. During the past 2

and a half years I have been working on trying to understand engineering disciplinary culture. This study has provided with significant findings that will help the engineering education community to better understand how students perceive their engineering disciplinary culture. However, I think this is just a start. There is a lot of work to be done in this area and understanding a complex construct like culture is not easy at all. Nevertheless by understanding that complex concept that makes students behave in a certain way, the engineering education field is advancing to make more informed decisions at every level. I hope this dissertation also brings more researchers from different fields to work together. There is a lot that we can learn from Industrial design for example. Similarly, researchers from business disciplines can work with us in engineering education to keep advancing in finding the right way to measure culture at the disciplinary level.

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Appendix A. Adapted Sharma's version of Hofstede's survey

First, we'd like to know a few things about your background.

What is your intended major? (Check all that apply.)

- ☐ Accounting and Information Systems
- ☐ Aerospace Engineering
- ☐ Agribusiness
- ☐ Agricultural and Applied Economics
- ☐ Agricultural Sciences
- ☐ Agricultural Technology
- ☐ Agriculture Undecided
- ☐ Animal and Poultry Sciences
- ☐ Apparel, Housing, and Resource Management
- ☐ Applied Economic Management
- ☐ Architecture
- ☐ Biochemistry (Agriculture & Life Sciences)
- ☐ Biochemistry (Science)
- ☐ Biological Sciences (Biology)
- ☐ Biological Systems Engineering
- ☐ Building Construction
- ☐ Business (undecided)
- ☐ Business Information Systems
- ☐ Business Information Technology
- ☐ Chemical Engineering
- ☐ Chemistry
- ☐ Civil and Environmental Engineering
- ☐ Classical Studies
- ☐ Communication
- ☐ Computer Engineering
- ☐ Computer Science
- ☐ Construction Engineering and Management
- ☐ Crop and Soil Sciences
- ☐ Dairy Science
- ☐ Decision Support Systems
- ☐ Economics (Business)
- ☐ Economics (Science)
- ☐ Education
- ☐ Electrical Engineering
- ☐ Engineering Science and Mechanics
- ☐ English
- ☐ Environmental Informatics
- ☐ Environmental Policy and Planning
- ☐ Environmental Resources Management
- ☐ Environmental Science

- ☐ Finance
- ☐ Fisheries Science
- ☐ Food Science and Technology
- ☐ Foreign Languages and Literatures
- ☐ Forestry
- ☐ French
- ☐ General Biosciences
- ☐ Geography
- ☐ General Engineering
- ☐ Geology
- ☐ Geosciences
- ☐ German
- ☐ Graphic Design
- ☐ History
- ☐ Horticulture: Environmental Horticulture
- ☐ Horticulture: Landscape Contracting
- ☐ Hospitality and Tourism Management
- ☐ Human Development
- ☐ Human Nutrition, Foods and Exercise
- ☐ Industrial and Systems Engineering
- ☐ Industrial Design
- ☐ Information Systems
- ☐ Interior Design
- ☐ International Studies
- ☐ Landscape Architecture
- ☐ Life Sciences Undecided
- ☐ Management
- ☐ Management Information Systems
- ☐ Management Science
- ☐ Marketing
- ☐ Materials Science and Engineering
- ☐ Mathematics
- ☐ Mechanical Engineering
- ☐ Meteorology
- ☐ Mining Engineering
- ☐ Music
- ☐ Natural Resources (undecided)
- ☐ Natural Resources Conservation
- ☐ Ocean Engineering
- ☐ Operations Management
- ☐ Philosophy
- ☐ Physics
- ☐ Political Science
- ☐ Pre-Health Professions
- ☐ Pre-Law
- ☐ Pre-Veterinary Medicine
- ☐ Psychology

- ☐ Public and Urban Affairs
- ☐ Real Estate
- ☐ Religion & Culture
- ☐ Russian
- ☐ Sociology
- ☐ Spanish
- ☐ Statistics
- ☐ Systems Assurance
- ☐ Theatre and Cinema
- ☐ University Studies
- ☐ Wildlife Science
- ☐ Wood Science and Forest Products
- ☐ Other (please type in below) _____

If you are in General Engineering, please select your intended major:

- ☐ Aerospace Engineering
- ☐ Biological Systems Engineering
- ☐ Building Construction
- ☐ Chemical Engineering
- ☐ Civil and Environmental Engineering
- ☐ Computer Engineering
- ☐ Computer Science
- ☐ Construction Engineering and Management
- ☐ Electrical Engineering
- ☐ Engineering Science and Mechanics
- ☐ Industrial and Systems Engineering
- ☐ Materials Science and Engineering
- ☐ Mechanical Engineering
- ☐ Mining Engineering
- ☐ Ocean Engineering

How many semesters have you been working on your degree?

- ☐ 1-2 semesters
- ☐ 3-4 semesters
- ☐ 5-6 semesters
- ☐ 7-8 semesters
- ☐ 9-10 semesters
- ☐ 10 or more semesters

Please rate your level of agreement with the following statements.

	Strongly disagree	Disagree	Disagree somewhat	Neither disagree or agree	Agree somewhat	Agree	Strongly agree
I would rather depend on myself than others.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
My personal Identity, independent of others, is important to me.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I rely on myself most of the time, rarely on others.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
It is important that I do my job better than others.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The well-being of my group members is important for me.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I feel good when I cooperate with my group members.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
It is my duty to take care of my family members, whatever it takes.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Family members should stick together, even if they do not agree.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

	Strongly disagree	Disagree	Disagree somewhat	Neither disagree or agree	Agree somewhat	Agree	Strongly agree
I easily conform to the wishes of someone in a higher position than mine.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
It is difficult for me to refuse a request if someone senior asks me.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I tend to follow orders without asking any questions.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I find it hard to disagree with authority figures.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
A person's social status reflects his or her place in society.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
It is important for everyone to know their rightful place in society.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
It is difficult to interact with people from different social status than mine.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Unequal treatment for different people is an acceptable way of life for me.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

	Strongly disagree	Disagree	Disagree somewhat	Neither disagree or agree	Agree somewhat	Agree	Strongly agree
I tend to avoid talking to strangers.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I prefer a routine way of life to an unpredictable one full of change.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I would not describe myself as a risk-taker.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I do not like taking too many chances to avoid making a mistake.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I find it difficult to function without clear directions and instructions.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I prefer specific instructions to broad guidelines.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I tend to get anxious easily when I don't know an outcome.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I feel stressful when I cannot predict consequences.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

	Strongly disagree	Disagree	Disagree somewhat	Neither disagree or agree	Agree somewhat	Agree	Strongly agree
Women are generally more caring than men.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Men are generally physically stronger than women.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Men are generally more ambitious than women.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Women are generally more modest than men.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
It is okay for men to be emotional sometimes.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Men do not have to be the sole breadwinner in a family.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Men can be as caring as women.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Women can be as ambitious as men.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

	Strongly disagree	Disagree	Disagree somewhat	Neither disagree or agree	Agree somewhat	Agree	Strongly agree
Respect for tradition is important for me.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I am proud of my culture.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I value a strong link to my past.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Traditional values are important for me.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I believe in planning for the long term.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I work hard for success in the future.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I am willing to give up today's fun for success in the future.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I do not give up easily even if I do not succeed on my first attempt.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

What is your gender?

- ☐ Male
- ☐ Female
- ☐ Prefer not to answer

What is your race? (Check all that apply.)

- ☐ American Indian or Alaska Native — Print name of enrolled or principal tribe.

- ☐ Asian — Please type in country of origin. _____
- ☐ Black or African American
- ☐ Hispanic — Please type in country of origin. _____
- ☐ Native Hawaiian
- ☐ White
- ☐ Other — Please type in race. _____
- ☐ Prefer not to answer

What is your current GPA?

- ☐ Less than 2.00
- ☐ 2.01 - 2.25
- ☐ 2.26 - 2.50
- ☐ 2.51 - 2.75
- ☐ 2.76 - 3.00
- ☐ 3.01 - 3.25
- ☐ 3.26 - 3.50
- ☐ 3.51 - 3.75
- ☐ 3.76 - 4.00

As part of this study, we are interested in talking to some survey respondents in more detail to better understand your responses. If you would be willing to be contacted for an interview, please provide your email address. Otherwise, leave this field blank.

Appendix B. Electronic consent form for survey

Thank you for taking the time to complete this survey. Your feedback is important to us in learning more about how students choose their majors. This survey should only take about 10 minutes of your time. Your participation in this survey is completely voluntary and confidential, and there are minimal to no risks involved. You must be at least 18 years of age to participate in this survey. Agreeing to participate is acknowledgment to the minimum age requirement. If you agree to participate in this survey, check the appropriate button below to continue to the next screen to begin the survey. Your confidentiality will be protected no matter which you select. By checking the agree button, you imply your consent to participate in this survey. If you have any questions about the survey, please contact us.

- ☐ I agree to take this survey and I am at least 18 years old.
- ☐ I do not agree to take this survey.

Appendix C. Interview participant - Screening survey

Thank you for taking the time to participate in our interview. The purpose of the study is to investigate patterns of cultural traits in students across disciplines, with the goal of building an actionable theory of engineering culture that can support pedagogies of inclusive and collaborative innovation. The following questions were developed to be able to make selections on the candidates we will interview, therefore the information will only be analyzed with the purpose of selecting the participants that we need for our research. The responses will not be stored. If you are not invited to participate in the interview responses to these questions won't be analyzed. If you are selected to participate we will contact you by email to set up a date and time for the interview.

- ☐ I agree to take this survey, to participate in the interview, and I am at least 18 years old.
- ☐ I do not agree to take this survey, nor participate in the interview

Please select your level of agreement with the following statements:

	Strongly disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Strongly Agree
1. Being good at [major] is important to me.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2. I feel like a real part of the [major] program.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3. It matters to me how well I do in [major] courses.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

What is your gender?

- ☐ Male
- ☐ Female
- ☐ Prefer not to answer

Please provide your email address: _____

Please provide your current major: _____

Appendix D. Mapping of questions

	Survey	Teaching and learning	Interview topics/questions
Uncertainty avoidance	<ol style="list-style-type: none"> 1. I tend to avoid talking to strangers. 2. I prefer a routine way of life to an unpredictable one full of change. 3. I would not describe myself as a risk-taker. 4. To avoid making a mistake, I do not like taking too many chances. 	<ol style="list-style-type: none"> 4. In the courses in my major, learning involves applying what I learn to new situations 5. In the courses in my major, I am encouraged to take risks and try new things 6. In the courses in my major, the focus is on learning abstract theories (developing understanding) 8. In the courses in my major, I learn by active participation and experimenting 	<p>Topics</p> <ol style="list-style-type: none"> 1. Values and epistemologies of each discipline 2. How work happens in their field 3. Knowledge development 4. Educational experiences <p>Probes</p> <ol style="list-style-type: none"> 1. Typical day in the classroom (clear rules) 2. Homework and exams (only one answer) 3. Learning process (need for clear steps) 4. Future expectations (try new things, create rules)
Individualism	<ol style="list-style-type: none"> 1. I would rather depend on myself than others. 2. My personal identity, independent of others, is important to me. 3. I rely on myself most of the time, rarely on others. 4. It is important that I do my job better than others. 	<ol style="list-style-type: none"> 1. Who is responsible for the learning process in the courses in your major? 3. In the courses in my major, learning involves memorizing and reproducing information and procedures exactly the way I am taught them 8. In the courses in my major, I learn by active participation and experimenting 9. In the courses in my major, I learn by watching others (like my teacher) and reflecting on what I am seeing and learning 	<p>Topics</p> <ol style="list-style-type: none"> 1. Values and epistemologies of each discipline 2. How work happens in their field 3. Knowledge development 4. Educational experiences 5. Expectations of education & career <p>Probes</p> <ol style="list-style-type: none"> 1. Typical day in the classroom (motivation to share with other students) 2. Homework and exams (individual/team grades/assignments) 3. Learning process (collective learning) 4. Future expectations (work for myself)
Power Distance	<ol style="list-style-type: none"> 1. I easily conform to the wishes of someone in a higher position than mine. 2. It is difficult for me to refuse a request if someone senior asks me. 3. I tend to follow orders without asking any questions. 4. I find it hard to disagree with authority figures. 	<ol style="list-style-type: none"> 2. Who does most of the talking in the courses in your major? 3. In the courses in my major, learning involves memorizing and reproducing information and procedures exactly the way I am taught them 7. In the courses in my major, the focus is on learning concrete procedures (practical application) 9. In the courses in my major, I learn by watching others (like my teacher) and reflecting on what I am seeing and learning 	<p>Topics</p> <ol style="list-style-type: none"> 1. Values and epistemologies of each discipline 2. How work happens in their field 4. Educational experiences 5. Expectations of education & career <p>Probes</p> <ol style="list-style-type: none"> 1. Typical day in the classroom (Teacher-student relationship) 2. Homework and exams (feedback process) 3. Learning process (only the professor has the knowledge) 4. Future expectations (obey the boss)
Masculinity	<ol style="list-style-type: none"> 1. Women are generally more caring than men. 2. Men are generally physically stronger than women 3. Men are generally more ambitious than women. 4. Women are generally more modest than men. 		<p>Topics</p> <ol style="list-style-type: none"> 1. Values and epistemologies of each discipline 2. How work happens in their field 5. Expectations of education & career <p>Probes</p> <ol style="list-style-type: none"> 1. Typical day in the classroom (gender equality)

Appendix E. Interview protocol

The interview purpose is to obtain more in-depth information about how students understand their disciplinary culture. It will collect data that go beyond the preliminary results found on the quantitative data. In addition, the interview will serve to improve the questions on the survey for future use. Interviews will help to answer the project research questions.

In general the topics to be discussed in the interview will be on how students perceive their major, and how those experiences relate to teaching, learning, and disciplinary culture. Participants will be selected from different majors and from different semesters, based on their responses in the survey. The topics to be discussed will be around the following aspects in their majors:

- 1) Values and epistemologies of each discipline
- 2) How work happens in their field
- 3) How is knowledge developed
 - a. What constitutes a "right" answer?
 - b. Who do they trust to know?
 - c. How long does it take to develop content knowledge?
- 4) Educational experiences: courses, industry, extra-curricular
- 5) Expectations of education & career
- 6) Industry versus academia values

Interviews will last 45 minutes, students that participate have already accepted to be contacted for the interview in the survey, nevertheless they will need to sign a consent form

before participating. Some of the participants (Freshmen and sophomore) will be interviewed for three years when possible in order to collect longitudinal data. The interviews will be digitally recorded and transcribed by the interviewer, and names will be removed from the transcriptions in order to ensure anonymity. The transcriptions will then be used to the data analysis process using the MAXQda software. Original transcripts will be storage in a safe place.

The interviewer will engage with the interviewee discussing the consent form and the interview topics described before. Some examples of the questions that will be asked are presented as follows:

In the first few questions, I'll ask you to respond by thinking of a specific class that you've taken that is important in your major. So, please think of such a class—what is the name of the class? what level is the class? When did you take it?

- This first questions are about how students interact with instructors in your major.

First, in that class, how did you interact with the instructor?

- How did other people in the class interact with the instructor?
- The next question is about how work is assigned and graded in your major. In that same class, what kind of work was assigned (tests, projects, papers/open-ended or right-or-wrong answers)?

In the following questions, the focus is on how the participants learn and understand the learning process.

- Now I'm going to ask you a few questions about learning in general. How do you approach learning new concepts?
- So far, we've been talking about your experiences in a specific course and in your major, but now I'd like to take a step back and ask you to describe your favorite learning experience, and tell me why you liked it, and what did you learn?
- Finally, given all the things we've talked about today, I'd like to understand a little bit about how and why you chose [major] as your major. What made you choose this field?
 - Did you consider other majors? If so, which ones and how did you choose among them?

Appendix F. Consent Form

VIRGINIA TECH

Informed Consent for Participants in Research Projects Involving Human Subjects

Title of Project: **A Longitudinal Study of the Dimensions of Disciplinary Culture to Enhance Innovation and Retention among Engineering Students**

Investigator(s): Marie Paretti, Tom Martin, Lisa McNair, Homero Murzi, Ryan Cook

Thank you for taking the time to provide information to our research. Your feedback is important to us in learning more about student's experiences and perceptions regarding their selected major.

I. Purpose of this Research/Project

The purpose of this study is to investigate patterns of cultural traits in students across disciplines, with the goal of building an actionable theory of engineering culture that can support pedagogies of inclusive and collaborative innovation. Participation is important because we are trying to understand how students perceive and experience their major. Therefore, we are collecting data in different ways (surveys, interviews, focus groups, observations of classes or students' work). Results from this study may be used for publication, dissertation, or a presentation.

II. Procedures (Please check all that apply)

Survey ☐ Interview ☐ Observations ☐ Focus groups ☐

For surveys, you will be asked to answer the questions provided online or in paper. Surveys shouldn't last more than 25 minutes. For interviews or focus groups, you will be asked to answer the questions based on your experiences and perceptions regarding your major. Interviews and focus groups will be conducted in a convenient site on campus and will be audio recorded. For observations, you will be asked to allow the researchers to video-record the presentation of your team's design project and use course assignment materials as data. Observations will occur during the class period of the course in its usual location and may be video-recorded. Participation in both the interview and the observations is not anticipated to exceed one hour.

III. Risks

The risk associated with participating in this research is minimal.

IV. Benefits

There are no direct benefits to participants. The data collected from participants during this research will be developed into one or more papers for publication in academic journals or for

presentation at professional conferences, which may help to improve engineering education practices.

V. Extent of Anonymity and Confidentiality

Your identity, and that of any individuals you mention, will be kept confidential at all times and will be known only to members of the research team. Interviews will be audio recorded and transcribed by a member of the research team. Observations may be audio- and video-recorded and later transcribed by a member of the research team. Researchers may also type or write notes that will not contain any personally-identifying information. When transcribing recordings or analyzing course data, pseudonyms (i.e. false names) will be used for my name and for the names of any other people you mention. These pseudonyms will also be used in preparing all written reports of the research. Any details in the audio- or video-recordings or course assignments that could identify you, or anyone you mention, will also be masked during the transcription process. After the transcribing is complete, the audio- and video-recordings will be stored in a secure online location, Scholar. The recordings, transcriptions and notes will be stored for five years and then destroyed. At no time will the researchers release identifiable results of the study to anyone other than individuals working on the project. The Virginia Tech (VT) Institutional Review Board (IRB) may view the study's data for auditing purposes. The IRB is responsible for the oversight of the protection of human subjects involved in research.

VI. Compensation

If you participate in an interview, you will be compensated with \$25. Otherwise, you understand that you will not be compensated for your participation.

VII. Freedom to Withdraw

It is important for you to know that you are free to withdraw from this study at any time without penalty. You understand that participation or withdrawal from the research study will not impact any course grade. You are free not to answer any questions that you choose or respond to what is being asked of you without penalty.

Please note that there may be circumstances under which the investigator may determine that a subject should not continue as a subject. Should you withdraw or otherwise discontinue participation, you will be compensated for the portion of the project completed in accordance with the Compensation section of this document.

X. Subject's Consent

I have read the Consent Form and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent to participate:

Signature

Date_____

Printed Name

Should you have any questions about this study, you may contact Dr. Marie Paretti at mparetti@vt.edu, or Homero Murzi at hmurzi@vt.edu or (215) 421-7588.

Should you have any questions or concerns about the study's conduct or your rights as a research subject, or need to report a research-related injury or event, you may contact the VT IRB Chair, Dr. Moore at moored@vt.edu or (540) 231-4991.

Appendix G. Extended Codebook

Theme	Code	Sub-code
What attracted you to the major?	Job Opportunities	
	Money	Knows someone in field
		Search for best paying jobs
	Interaction with people	
	Perceived as good at it	Good at math
		Good at design
	Good women/men balance	
	Parent influence / role	Parent has the same profession
		Parent want them to be in the profession
		Someone they admire is in the profession
Someone they respect wanted them to be in the profession		
What does the major value?	Interpersonal Skills	
	Wanting to Learn	
	Getting a Good Grade	
	Develop professional network - know professors	
	Understanding how things work	
	Gender balance	
	Professional and technical skills (Balance)	
	Creative thinking	
	Always know what to do	
	Accreditations	
	Ethics	
	Collaboration / teamwork	
	One right answer	
	Real world application /examples	
	Ambiguity Tolerance- Low	
	Creativity	
	Strategic communication	

Theme	Code	Sub-code
How is it taught? (Teaching process)	Pedagogy	Group Projects
		Solving problems/practicing with examples
		Lecture
		Technology in Class
		Active learning
		Use of great examples
		Discussion-based
	Grading Process	Individual Grades
		Group Grades
		Deadline
		Peer evaluation
		Rubric
		Feedback
		One right answer
		Partial credit
		In charge of grading
	Faculty Student Interactions	Limit/lack of Interaction
		Encouraged Interaction
		Student's talked
		Ask respond questions
		Support of good TA
		Singling out women
	Assignments	Forced Response
		Open ended Questions
		Homework, Quizzes, Project, Test
		Problem Based
		Individual vs. group
		Clear rules
	Approachable	Encouraged Student Collaboration
		Students Felt Safe In Class
		Care for Students
		Encouraged to ask questions
		Office Hours
		Email
		Respect for knowledge
		Passion
		Communication
	Encouragement to participate	Asking good questions

		Less formal figure (TA) motivates participation
		Need to clarify (having a question)
		Pressure to talk (be on the spot)
	Class rules	Structured
		Complexity
		Reading load
		Class size
		Attendance
		Pay attention
	Team interactions	Social loafing
How do you learn? (Learning process)	Individually Then Group	
	Hands on activities	
	Self Directed (Research/reading)	
	Pay attention in Class	
	Ask Peers	
	Likes group work because each person has unique skill	
	Learns through repetition	
	Prefers Open-Ended Questions	
	Ask good questions	
	Taking good notes	
	Ability to solve problems	
	Ability to teach it to someone	
	Out of the classroom	
	Felling pressure minimizes learning	
	Following peers	
	Memorization	
Why do you learn?	Prestige	
	Curiosity or interest	
	Good Grade	
	Need to know for future job	
	Know I learned	Extracurricular
		See content at internship
		Can solve problem
		Apply on a project
		Grades
		Can Teach it to Someone
	Enjoy the class	
	Passion of the instructor	

Theme	Code	Sub-code
How will you use it in the future?	Using class material for internship	
	Learning professional skills to develop network	
	Developing problem-solving process	
	Teamwork experiences in class to know how to collaborate	