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Original Paper

Measuring Disciplinary Perceptions of Engineering from a Cultural Lens: A Validation of an Instrument in a Research Technical University

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Abstract

Engineering culture is a complex phenomenon that needs to be understood to promote the value of professional skills and not only the technical skills that have been traditionally valued in engineering. This study investigates ways to identify patterns of cultural traits in undergraduate engineering students, by using and validating an instrument originally developed to measure national culture. This study was conducted in three phases: in Phase 1, we validated an instrument to measure engineering culture based on Hofstede's model of national culture. In this phase, we conducted an exploratory factor analysis and a reliability analysis with responses of 1261 undergraduate students. In phase 2, we identified how the dimensions in Hofstede's model mapped and differed between academic engineering disciplines. To accomplish that goal, we conducted descriptive statistics and an analysis of the variance of responses of 794 engineering students. In phase 3, we analyzed if some of Hofstede's dimensions are inherent to prospective engineering students or if they were influenced by their specific engineering programs. In phase 3, we collected data from 1,330 first-year engineering students and compared them with data from the same students at the end of their first year. Moreover, for three specific majors, we compared them with data of 261 senior students. Results demonstrated the validity of the instrument in academic disciplines and showed that the uncertainty avoidance dimension of Hofstede's model differed between three engineering majors (i.e., ECE, ISE, and CS). This dimension did not differ after the first year but changed in the senior year.

Keywords

Engineering culture, instrument validation, Hofstede's dimensions, disciplinary culture

1. 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 successful professional engineers. Some of the most important professional skills are considered to be teamwork, creativity, problem-solving, and adaptive expertise (Jesiek, Zhu, Woo, Thompson, & Mazzurco, 2014; Redish & Smith, 2008; Terenzini, Cabrera, Colbeck, Bjorklund, & Parente, 2001). Faculty members in engineering often struggle to provide such skills without sacrificing discipline-specific problem-solving competencies (Clough, 2004). Interestingly, the inability to promote these skills without sacrificing technical skills is often attributed to the cultural traits of the field, which is often characterized as masculine, individualistic, structured, and function-oriented. However, as Godfrey and Parker stated, "much of this discourse around cultural change has been incorrectly based on the assumption that engineering educators are familiar with theories and models of culture and cultural change" (Godfrey and Parker (2010), p. 5). Furthermore, it is not clear how engineering culture has an impact on different curricular expectations and changes (Baba & Pawlowski, 2001; Godfrey & Parker, 2010; Merton, Froyd, Clark, & Richardson, 2004). Hence, we argue that it is important to understand the complex phenomenon of engineering culture in order to find a different approach to promote the value of professional skills and effectively integrate them into the engineering curriculum. Without a better understanding of engineering culture, promoting changes becomes challenging as engineering educators and administrators might not be familiar with the complexity of this phenomenon. Understanding culture helps us to demonstrate the value of professional skills and not only the technical skills that have been traditionally valued in engineering.

To better understand engineering culture, this study investigates ways to identify patterns of cultural traits in undergraduate engineering students. To frame this study, we applied a very well-known theory used in sociology and business developed by Hofstede (1993) and its constructs of dimensions of national cultures (i.e., power distance, uncertainty avoidance, individualism, masculinity). We hypothesized that Hofstede's model of dimensions of national cultures could be used to understand engineering culture because research on academic disciplines typically understands majors as social units with cultural identity (Becher, 1994). Particularly, we wanted to identify if Hofstede's lens is a valid theory to measure patterns of disciplinary culture in engineering. We considered Hofstede's theory to be adequate to explore this phenomenon not only because of how widely it has been implemented to study culture in different contexts around the world, but also because of the authors' familiarity with its use in engineering education (Murzi Escobar, 2016; Murzi, Martin, McNair, & Paretti, 2014, 2015; Murzi, Martin, McNair, & Paretti, 2016).

We recognize that Hofstede's model provides information on culture at the national level rather than at the disciplinary level. Nevertheless, the results of this study provided valuable information to understand the validity of Hofstede's model in engineering disciplines, and to explore some aspects of engineering students' perceptions of culture at different levels in their academic program. For example, we were able to identify in three specific engineering majors that there were significant changes between students in their first year, and students in their senior year.

1.1 Research Purpose and Study Overview

The purpose of this study was threefold: 1) to validate an instrument to measure engineering culture based on Hofstede's model of national culture, 2) to identify how the dimensions in Hofstede's model differ between academic engineering disciplines, and 3) to understand if some of these dimensions are inherent to prospective engineering students or if they are influenced by their specific engineering programs.

To achieve the purpose of this study, we divided the study in three phases respectively: in phase 1, to understand how Hofstede's dimensions can be used to understand engineering culture, we analyzed and validated an instrument specialized in measuring engineering disciplinary culture based on Hofstede's model (i.e., a survey developed by Sharma (2010)). We conducted an exploratory factor analysis and a reliability analysis with responses of 1261 undergraduate students from 55 different majors at a research university. Results showed that Sharma (2010) instrument is a valid and reliable measure of the cultural traits in engineering.

In phase 2, to identify how the Hofstede's dimensions of national culture map and differ between engineering disciplines, we conducted descriptive statistics of responses of 794 undergraduate engineering students representing how each major scored in all of the four dimensions. Furthermore, we conducted an analysis of variance (ANOVA) to determine if such dimensions differed between academic disciplines. Results showed that only one of Hofstede's dimensions (i.e., *uncertainty avoidance*) differed only between three specific majors: Electrical and Computer Engineering (ECE), Industrial and Systems Engineering (ISE), and Computer Science (CS).

In phase 3, based on the results of phase 2 we decided to explore in-depth if the *uncertainty avoidance* was inherent to prospective engineering students or if the engineering programs influenced it. We collected data from 1,330 first-year engineering students at the same research institution and compared them with data from the same students at the end of their first year. Furthermore, we compared results from this dimension in the ECE, ISE and CS majors with data from 261 senior students of those specific majors. Results indicated that uncertainty avoidance did not differ after the first year but changed in the senior year.

2. Theoretical Background

To study culture at the disciplinary level, we used 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.

Hofstede and Hofstede (2001) introduced a conceptualization of dimensions of national culture after analyzing cultural differences among nations. They surveyed 88,000 employees at IBM distributed in 66 countries and 50 occupations. Although the questions looked to capture values, Hofstede and Hofstede (2001) stated that these constructs were able to capture what is "desirable vs. desired" (p. 43). Hofstede and Hofstede (2001) 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 argument, the authors used these 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.

More recently, G. Hofstede, G. Hofstede, and M. Minkov (2010a) defined culture as a "system of shared meanings that may be unique to a particular society or a group of societies" (p. 4). Hofstede's model (Hofstede et al., 2010a; G. Hofstede, G. J. Hofstede, & M. Minkov, 2010b; Minkov, 2012) defined the dimensions of culture as 1) ***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, 2011); ***uncertainty avoidance:*** the degree to which members of a culture can operate comfortably with uncertainty (Hofstede, 2011); 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., 2010b).

Hofstede's model of cultural dimensions can be a practical framework to understand and interpret aspects of disciplinary culture from constructs successfully used to measure cultural differences at the national level. For example, **power distance** can help explain how students understand authority in the classroom and faculty-student relationships, **individualism** can help explain how students understand collaboration with other students and interactions with other disciplines, **uncertainty avoidance** can provide insights on students' comfort levels with structure and clear rules, and **masculinity** can provide information regarding students' perceptions of gender equality in engineering. Applying Hofstede's perspective can provide additional information in engineering education to better understand how students perceive their disciplinary culture because this model provides information related to 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. Hofstede's model has been proven, in a variety of contexts, to be reliable (Ang, Van Dyne, & Begley, 2003; Ardichvili & Kuchinke, 2002; Hoppe, 1998; Merritt, 2000; Yoo, Donthu, & Lenartowicz, 2011) and valid in identifying cultural differences (Chiang, 2005; De Mooij, 2010; Hoppe, 1998; Merritt, 2000; Mouritzen & Svara, 2002; Shane, Venkataraman, & MacMillan, 1995). 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., 2010a); therefore, information obtained from these constructs can provide a better understanding of how well Hofstede's theory is able to explain some of the characteristics of the disciplinary engineering culture.

Hofstede's constructs can provide guidance to narrow down some of the complex features of engineering culture by having a focus on aspects of culture that can relate to academic disciplines rather than to the society in general.

3. Research Process

As mentioned, the purpose of this study was threefold: 1) to understand how Hofstede's dimensions allow understanding engineering culture, 2) to understand if such dimensions map and differ between academic engineering disciplines, and 3) to understand if some of those dimensions are inherent to prospective engineering students or if they are influenced by the engineering programs. To achieve the purpose of this study, we divided it into three phases respectively. This section will explain each phase, including its methods and results.

3.1 Phase 1

The goal of Phase 1 was to understand how Hofstede's dimensions can be used to understand engineering culture. In this phase, we analyzed and validated an instrument specialized in measuring engineering disciplinary culture based on Hofstede's model. We conducted an exploratory factor analysis and a reliability analysis with responses of 1261 undergraduate students from 55 different majors at a research university. The following paragraphs detail this phase. Results showed that the survey developed by Sharma (2010) is a valid and reliable measure of the cultural traits in engineering.

3.1.1 Methods

Data collection: We collected quantitative data using an improved version of Hofstede's original survey. 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. Although our literature review identified more than 20 adapted versions of Hofstede's surveys, only three versions thoroughly explained their processes of affirming validity and reliability. We selected the version of Hofstede's instrument developed by Sharma (2010) for several reasons: Sharma used some of Hofstede's initial items and improved some of the questions and followed a rigorous process of scale development and validation. The author established face and content validity using the expertise of a panel of judges. He conducted a scale refinement and purification study, followed by a scale validation study. And ultimately, he was able to establish convergent, discriminant, nomological, and predictive validity (Sharma, 2010). Sharma proposed eight constructs in his survey to measure Hofstede's dimensions of culture: **Individualism (INDV)** is measured by the negative correlation between the constructs of independence

(IND) and interdependence (INT). **Power distance (PDI)** is measured by the positive correlation between the constructs of power (POW) and social inequality (IEQ). **Uncertainty avoidance (UAI)**, by the positive correlation between risk avoidance (RSK) and ambiguity intolerance (AMB). Finally, **Masculinity (MAS)** is measured with the construct of gender equality (GEQ).

The selected version of the survey was administered online using Qualtrics. The University's assessment office sent an email inviting all undergraduate students to participate in the study. Students participating approved an electronic consent form on the first page of the survey. Students took no more than 25 minutes to fill out the 38 items survey. Data about GPA, demographics, major, and semester were also collected.

Participants and sample: The survey was administered during Fall 2013 with 1261 undergraduate students at a Research University. The sample included students from 55 different majors, however, 80% of the responses came from majors in engineering. The completion rate was 87%, out of 1,449 students that started the survey, 1261 students finished it. To reduce the number of lost cases, and to avoid biases, missing data were imputed following Dempster, Laird, and Rubin (1977) procedures of the Expectation-Maximization algorithm. Missing values were random as probed by the little's missing completely at random test (MCAR) (chi-square = 261.120, DF = 974, and sig. = 0.980).

3.1.2 Results

Using the Statistical Package for the Social Sciences (SPSS), we conducted an exploratory factor analysis to demonstrate the validity of the 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 eight factors (see Table 1) using principal axing factoring as the extraction method. In order to determine how many factors to retain, we used Kaiser's criterion (i.e., retaining all factors that are above the eigenvalue of 1) (Yong & Pearce, 2013).

Table 1. Exploratory Factor Analysis—Total Variance Explained

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loading
	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	100.00

Extraction Method: Principal Axis Factoring.

In addition, because culture is a social construct and behaviors and values cannot be totally partitioned into individual units that work independently from one another, we anticipated some correlation among the factors, hence we used a Promax rotation method (Yong & Pearce, 2013) to cluster the survey items (see Table 2). The pattern matrix showed that the factors loading together are the same constructs developed by Sharma (2010), increasing the validity of his instrument.

Table 2. Exploratory Factor Analysis—Pattern Matrix after Rotation

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

Rotation Method: Promax with Kaiser Normalization.

*Rotation converged in 7 iterations.

We conducted an analysis of reliability using Cronbach alpha and including alpha if item deleted. Results from the analysis (see Table 3) demonstrated internal consistency in Sharma's constructs.

Table 3. 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

After tests demonstrated reliability and construct validity of the Sharma [10] instrument, data were collected in phase 2 to understand Hofstede's dimensions scores in undergraduate students. However, the sample size for majors outside engineering was very small and not representative. Therefore, we focused on the analysis and discussion of the results of this study only on engineering majors.

3.2 Phase 2

The goal of Phase 2 was to identify whether Hofstede's theory of dimension of national culture maps to academic engineering disciplines. In this phase, we conducted descriptive statistics of responses of 794 undergraduate engineering students representing how each major scored in all of the four dimensions. We also conducted an analysis of variance (ANOVA) to determine if such dimensions differed between academic disciplines. Results showed that two of the Hofstede's dimensions (i.e., uncertainty avoidance and independence) differed between three specific majors (i.e., Electrical and Computer Engineering (ECE), Industrial and Systems Engineering (ISE), and Computer Science (CS)), and within these three majors, the uncertainty avoidance varied over time.

3.2.1 Methods

Data collection and sample: We collected data in Spring 2014 and Fall 2014 from 794 undergraduate engineering students using Sharma (2010) version of Hofstede's instrument. Table 4 provides detailed information about the sample.

Similarly, the University's assessment office sent an email to all undergraduate engineering students inviting them to participate in the study; we also collected consent, GPA, demographics, major, and semester. Similar to phase 1, students took no more than 25 minutes to fill out the 38 questions survey.

Results: To identify whether Hofstede's theory of dimension of national culture maps to academic engineering disciplines, we conducted descriptive statistics representing how each major scored in all of the four dimensions (see Table 5). To determine if there were significant differences in the mean of students' responses in each engineering major, we conducted a one-way analysis of variance (ANOVA), post hoc analysis and t-tests.

Table 4. Characteristics of the Sample

Characteristic	**Students n= 794**	**Percentage**
Discipline		
Aerospace engineering (AE)	75	9.45%
Chemical engineering (CE)	57	7.18%
Civil engineering (CEE)	71	8.94%
Computer science (CS)	80	10.08%
Electrical and computer engineering (ECE)	187	23.55%
Engineering science and mechanics (ESM)	26	3.27%
Industrial and systems engineering (ISE)	154	19.40%
Material sciences engineering (MSE)	24	3.02%
Mechanical engineering (ME)	89	11.21%
Mining engineering (MIE)	19	2.39%
Ocean engineering (OE)	12	1.51%
Gender		
Female	187	23.55%
Male	565	71.16%
Prefer not to answer	42	5.29%
Race/Ethnicity		
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%
Level		
Freshmen	180	22.67%
Sophomore	226	28.46%
Junior	166	20.91%
Senior	222	27.96%

Results from the ANOVA showed some differences between majors in the constructs of **Independence** (IND) [F(10, 783) = 11.28, p < 0.05] and the two constructs that compose uncertainty avoidance (UAI): **ambiguity intolerance** (AMB) [F(10, 783) = 26.12, p < 0.05] and **risk aversion** (RSK) [F(10, 783) = 2.33, p < 0.05]. The analysis indicated no significant differences (p<0.05) between majors in interdependence (INT), power (POW), social inequity (IEQ), gender equality (GEQ), and masculinity (MAS).

To identify which majors had differences, we conducted post hoc comparisons using the Tukey HSD test because our data met assumptions of homogeneity. Results indicated that: **Independence** (IND) mean score for ECE (M = 5.47, SD = 1.855) was statistically significantly lower than the mean score for ISE (M = 5.61, SD = 1.234), AE (M = 5.74, SD = 1.171), and MIE (M = 5.91, SD = 0.995). In addition, the post hoc comparison indicated that the **ambiguity intolerance** (AMB) mean score for ISE (M = 4.49, SD = 1.505) was statistically significantly lower than CS (M = 4.53, SD = 1.613), and ECE (M = 4.65, SD = 1.387). Similarly, the **risk aversion** (RSK) mean score for ISE (M = 3.85, SD = 1.453) was statistically significantly lower than ECE (M = 4.16, SD = 1.386), and CS (M = 4.38, SD = 1.663).

These differences in individualism (more specifically, the construct of independence) and uncertainty avoidance dimensions required a more detailed analysis to determine when the variations in the scores happened, that is, in which stage of the major these dimensions changed.

Table 5. Scores by Engineering Major

	N	Individualism		Power Distance		Uncertainty avoidance		Masculinity	
		INT	IND	POW	IEQ	RSK	AMB	MAS	GEQ
ECE	187	2.16	5.47	4.03	3.10	4.16	4.65	4.26	6.14
CS	80	2.36	5.64	3.85	2.77	4.38	4.53	4.22	6.19
ISE	154	1.98	5.61	4.03	3.02	3.85	4.49	4.32	6.02
AE	75	2.14	5.74	4.12	2.93	3.98	4.37	4.21	6.05
CE	57	2.03	5.58	4.06	2.82	4.32	4.73	4.07	6.19
CEE	71	1.93	5.68	4.35	2.96	4.05	4.59	4.09	6.12
ESM	26	2.14	5.53	4.08	2.81	4.25	4.82	4.32	6.11
MSE	24	1.99	5.84	3.94	2.91	4.51	4.94	4.57	6.26
ME	89	2.09	5.76	4.04	3.07	4.23	4.56	4.17	5.96
MIE	19	1.95	5.91	3.92	3.17	3.74	4.43	4.16	5.51
OE	12	2.02	5.54	4.17	3.10	4.44	4.38	4.07	6.00

3.3 Phase 3

Phase 3 sought to explore in-depth if the uncertainty avoidance was inherent to prospective engineering students or if the engineering programs influenced it. We collected data from first-year engineering students and compared them with data from the same students at the end of their first year. Furthermore, using t-tests we compared results from this dimension in the ECE, ISE and CS majors with data from 261 senior students of those specific majors. Results indicate that the uncertainty avoidance did not differ after the first year but changed in the senior year.

3.3.1 Methods

Data collection and sample: We collected data in Fall 2015 from 1,330 first-year undergraduate engineering students at the same research institution as the previous phases using the uncertainty avoidance questions of the Sharma (2010) version of Hofstede's instrument.

Approved by the Institutional Review Board (IRB), we were able to include these questions in the mandatory survey that first-year engineering students took before and after their first semester. Students had to take the survey as an assignment of their first-year general engineering course. Students accessed the online survey through their university's course management system, but we did not have access to information regarding how much time it took the students to fill out the eight questions of the survey.

Although we would want to know more about the Individualism component, we used only the *uncertainty avoidance* questions because we only had access to include eight questions in the mandatory survey and the uncertainty avoidance dimension showed interesting results in phase 2. Students reported the major they want to pursue at the end of their first year. Data from senior students were collected in phase 2 from ECE, ICE and CS majors.

Results: To determine if their perceptions regarding uncertainty avoidance changed during their first semester in engineering, we conducted a paired-samples t-test comparing the **uncertainty avoidance** elements of engineering students before and after their first year. We used the students' identifiers in the mandatory survey to pair the responses of the pre-and-post test. Results from the paired-samples t-test did not show any statistically significant difference by major as shown in Tables 6 and 7.

Table 6. Pre-and-post Test Paired-samples t-test Results for Ambiguity Intolerance

Intended Major		n	M	SD	t	df	Sig.
ISE	PRE	272	4.61	1.218	1.163	279	0.097
	POST		4.49	1.259			
CS	PRE	102	4.85	1.174	1.129	101	0.262
	POST		4.71	1.177			
ECE	PRE	314	4.48	1.356	2.328	142	0.211
	POST		4.22	1.282			
AE	PRE	79	4.74	1.132	1.056	98	0.294
	POST		4.59	1.335			
CHE	PRE	72	4.41	1.060	-0.254	23	0.801

	POST		4.47	1.258			
CEE	PRE	145	4.95	1.122	0.651	46	0.622
	POST		4.78	0.907			
ESM	PRE	51	4.76	1.198	0.017	111	0.986
	POST		4.76	1213			
MSE	PRE	62	4.79	1.242	0.999	87	0.321
	POST		4.61	1.319			
ME	PRE	205	4.45	1.126	2.212	41	0.366
	POST		4.28	1.427			
MIE	PRE	9	4.44	1.303	-.0231	37	0.818
	POST		4.48	1.336			
OE	PRE	19	4.46	1.196	-0.653	178	0.515
	POST		4.53	1.395			

However, we also conducted a t-test comparing the scores for ambiguity and risk aversion from first-year students with data from senior students in the three majors whose results were different compared to other majors in phase 2 (i.e., ECE, ISE, and CS). Data showed statistical significance in the differences in the scores for ambiguity and risk. Tables 8 and 9 show the t-test results.

Table 7. Pre-and-post Test Paired-samples t-test Results for Risk Tolerance (RSK)

a		n	M	SD	t	df	Sig.
ISE	PRE	272	3.74	1.205	-0.761	279	0.447
	POST		3.80	1.021			
CS	PRE	102	4.04	1.206	-1.340	101	0.183
	POST		4.20	1.193			
ECE	PRE	314	3.86	1.196	0.94	142	0.925
	POST		3.65	1.213			
AE	PRE	79	3.84	1.101	-0.057	98	0.954
	POST		3.84	1.230			
CHE	PRE	72	3.75	1.020	-0.292	23	0.773
	POST		3.81	1.109			
CEE	PRE	145	3.67	1.171	0.350	46	0.729
	POST		3.59	1.269			
ESM	PRE	51	3.83	1.196	-0.770	111	0.442
	POST		3.91	1.277			
MSE	PRE	62	3.77	1.143	0.104	87	0.917

	POST		3.75	1.185			
ME	PRE	205	3.64	1.194	0.901	41	0.376
	POST		3.33	1.267			
MIE	PRE	9	3.75	1.056	-1.102	37	0.314
	POST		3.89	1.105			
OE	PRE	19	4.03	1.191	0.983	178	0.327
	POST		4.53	1.395			

Table 8. Independent Samples t-test Results for Ambiguity Intolerance

Intended Major		n	M	SD	t	df
ISE	First-year	272	4.49	1.259	3.122*	182
	Senior	95	3.61	1.599		
CS	First-year	102	4.71	1.177	1.438*	157
	Senior	57	5.25	1.061		
ECE	First-year	314	4.22	1.282	-0.991*	310
	Senior	109	5.31	0.855		

* p<0.05

Table 9. Independent Samples t-test Results for Risk Aversion

Intended Major		n	M	SD	t	df
ISE	First-year	272	3.80	1.021	12*	182
	Senior	95	3.19	1.491		
CS	First-year	102	4.20	1.193	1.210*	157
	Senior	57	4.63	1.237		
ECE	First-year	314	3.65	1.213	2.838*	310
	Senior	109	4.47	1.632		

* p<0.05

These results were consistent with the t-tests we conducted with data from phase 2 comparing sophomore and senior students' scores in the same three majors. Although the sample size from sophomores was relatively low, we selected sophomore because they have a better understanding of the engineering major and have formed their perceptions about the purpose and meaning of the major. Based on the t-test results ($t(12)= -2.014$, $p<0.05$) (see table 10 and 11), sophomores students in ECE ($M= 4.04$, $SD= 1.150$) were associated with a significant lower score on **risk aversion** than senior students ($M= 4.47$, $SD= 1.632$). The t-test ($t(23)= 0.983$, $p<0.05$) showed that the difference is even higher in **ambiguity intolerance** ($M=4.52$, $SD=1.03$ in sophomores to $M=5.31$, $SD=0.85$ in seniors).

Also, the t-test (t(6)= 6.223, p<0.05) revealed that CS sophomores **risk aversion** score (M= 4.21, SD= 1.172) was lower than CS seniors **risk aversion** score (M= 4.63, SD= 1.237)), and CS sophomores **ambiguity intolerance** score (M= 4.66, SD= 1.377), was lower than CS seniors **ambiguity intolerance** score (M= 5.25, SD= 1.061), (t(17)= 1.789, p<0.05). ISE seniors' scores on **risk aversion** (M= 3.19, SD= 1.491) decreased significantly (t(33)= 1.879 p=0.05) when compared with sophomores (M= 3.73, SD= 1.16). Similarly, there was a significant decrease on **ambiguity intolerance** (Seniors M=3.61 SD=1.60 and Sophomores M=4.62 SD=1.45)

Table 10. Independent Samples t-test Results for Risk Aversion between Sophomore and Senior Students

Intended Major		M	SD	t	df
ISE	Sophomore	3.73	1.16	1.879*	33
	Senior	3.19	1.49		
CS	First-year	4.21	1.17	6.223*	6
	Senior	4.63	1.24		
ECE	First-year	4.04	1.15	2.014*	12
	Senior	4.47	1.63		

* p<0.05

Table 11. Independent Samples t-test Results for Ambiguity Intolerance between Sophomore and Senior Students

Intended Major		M	SD	t	df
ISE	Sophomore	4.62	1.45	3.122*	31
	Senior	3.61	1.60		
CS	First-year	4.66	1.38	1.789*	17
	Senior	5.25	1.06		
ECE	First-year	4.52	1.03	0.983*	23
	Senior	5.31	0.85		

* p<0.05

These results indicate that ECE and CS students are less comfortable with ambiguity and risk-taking as they advance in their program. In contrast, data suggests that ISE students tend to get more comfortable with ambiguity and risk over time.

4. Discussion and Conclusions

In this section, we describe in more detail how the results can inform the understanding of disciplinary culture in engineering majors. Furthermore, we explain the use of Hofstede's theory of dimensions of national cultures in academic settings. Finally, we suggest implications for future research.

Our factor analysis and reliability results in phase 1, indicated that we can use with confidence the survey developed by Sharma (2010) to understand engineering culture using Hofstede's dimensions. Our results in phase 2 corroborated this finding and indicated that Hofstede's theory of dimension of national culture maps to academic engineering disciplines. Furthermore, our results suggest that there are significant differences between the dimensions of engineering culture only in some majors (i.e. ECE, ISE, CS). More specifically, ISE **uncertainty avoidance** elements scores of engineering culture were lower than the uncertainty avoidance scores of ECE and CS, and the **independence** dimension of ECE major is lower than ISE, AE, and MIE. Finally, our results in phase 3 indicate that the differences in **uncertainty avoidance** elements increased overtime: ISE scores of RSK and AMB are lower in the senior year whereas ECE and CS scores of RSK and AMB increase in the senior year. Our results in phase 3 also indicate that the **uncertainty avoidance** elements did not change during the first year of any of the majors. Results in phase 3 suggested that these three programs influenced change in the uncertainty avoidance elements of ECE, ISE, and CS.

In the following sections, we will elaborate on each dimension based on the results obtained.

4.1 Individualism

According to Hofstede (2011), individualism refers to the degree people in a system are integrated with other members of the system. 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).

Based on the different curricular structures of the majors, it is a common belief the existence of differences in the way students in ISE, for example, approached teamwork, compared to other disciplines like ME, AE or ECE. This belief arises from the fact that the ISE curriculum, in the university studied, has a strong focus on teamwork, whereas AE or ECE has a strong focus on individual work. However, our **results indicate no significant evidence of such differences and no significant changes** in this dimension in engineering students**.** Mean responses in Table 5 indicates that all engineering majors studied had similar scores regarding the two constructs used to analyze individualism (INT and IND). Nevertheless, the limitations of our study do not allow us to make broader generalizations. Further research on individualism using a qualitative approach would help to understand the cultural effect of students' experiences working in teams or in projects that require interdisciplinary collaboration.

4.2 Power Distance

Hofstede (2011) defined power distance as the extent to which a given system supports unequal power distribution. As expected, our results indicate that **there is no evidence of 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.

4.3 Masculinity

According to Hofstede (2011), masculinity refers to the distribution of values between genders. This dimension is very important for the understanding of disciplinary cultures in engineering majors not only because it may provide information that helps change the masculine perception of the engineering field, but it can also provide information to improve inclusion, diversity, and to make engineering schools more welcoming. Results from the survey suggested that **there are no significant differences** in cultures of different majors in terms of the two constructs developed by Sharma to study masculinity (MAS and GEQ). However, every engineering major that participated in the study had a high score, which indicates that all of the engineering programs were associated with assertiveness and competition.

4.4 Uncertainty Avoidance

Uncertainty avoidance refers to a culture's tolerance for ambiguity. It indicates the extent members of the culture feel comfortable or uncomfortable with the lack of structure in different situations (Hofstede, 2011). In addition, this dimension can help to 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. Such conditions are required in every engineering discipline.

Data suggest that this was the dimension that provided more information to understand differences between engineering majors. 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 ISE, ECE, and CS. ISE has lower scores of both RSK and AMB, which suggests that ISE students are more comfortable with less structure, less clear rules, and taking more chances. Also, ECE and CS have higher scores of RSK and AMB, indicating that students in these majors would be less comfortable in situations that demand uncertainty. Similarities between results of ECE and CS can also be attributed to the fact that the disciplines belong to the same academic department in the university studied.

In addition, we were able to identify that students' perceptions of uncertainty avoidance did not change during the students' first year at our study site. This was expected because it is very difficult that students change their perceptions of national culture over one semester, especially when during the first year, engineering students are altogether taking general engineering classes. In the second year, each student selects a major and starts taking classes in their respective academic discipline. Students in ECE and CS scored higher in uncertainty avoidance over time. The opposite trend occurred with students in ISE. The fact that scores in this dimension changed is very relevant because it is possible that the majors influenced that change. Although, such change might not be in the desired direction for certain majors. Our results indicate that students entering engineering have more acceptance of uncertainty, hence more prone to take risks, however as semesters passed, the academic system punishes the mistakes and pressure students to have the right answer, therefore students tend to be more risk-averse.

5. Limitations and Implications

The purpose of this study was to understand better the dimensions of engineering culture, if they differ between academic engineering disciplines, and if some of these dimensions changed for engineering students. Because currently there is not a direct measure of cultural dimensions that can be administered at a large scale, we favored a survey format based on self-report data to enhance the generalizability of findings and advance understanding in this area (McGrath, Martin, & Kulka, 1982). However, in *phase 2* the extent of the generalization of the findings is limited because the sample size might not be representative of the individual majors studied. It was possible to make inferences of the engineering student population from the specific research university but we caution to generalize these results to the engineering students' population as a whole.

We acknowledge that Hofstede's model was created to provide information on culture at the national level rather than at the disciplinary level. Therefore, Hofstede's model could lack the precision that allows us to find evidence of bigger cultural differences between all the majors. However, we were able to identify some patterns in three different engineering disciplines that we could investigate more in-depth. Further research could be informed by these findings and attempt to develop a more precise instrument to answer if there are substantial cultural differences between other engineering disciplines.

In phase 2 students reported their intended major, which might not necessarily be the major they selected or were admitted at the end of their first year. We could not know if they ultimately selected those majors or changed their minds. Furthermore, we recognize a threat to internal validity in phase 3 defined by Creswell and Clark (2011) as testing threats where students might become familiar with the test in a pre-and-post setting. To minimize this threat, and having a longer time interval between the administration of the tests, we conducted the pre-test in the first week of the semester and the post-test four months after.

Our findings provided information that can have an impact on research and practice. For research, there is value in engineering education in the process of using frameworks developed for other 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.

Results also provided 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 is known that 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.

This study described a quantitative investigation of disciplinary culture in engineering majors. We confirmed the validity and reliability of Sharma's instrument. However, the model did not map strong differences between 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. Further qualitative research with students in ISE, CS, and ECE would provide interesting information to identify how the students perceive and understand their majors in terms of cultural differences.

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