2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #34905

Women's Autonomy, Relatedness and Competence: A Comparison of Engineering Programs in Two Different Cultures

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She has also incorporated theories on social cognitive career choices and student attrition mitigation to investigate the effectiveness of institutional interventions in increasing the retention and academic success of talented engineering students from economically disadvantaged families. She's also involved in a project that explores the relationship between the institutional policies at UPRM and faculty and graduate students' motivation to create good relationships between advisors and advisees.

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Abstract

Despite the extensive efforts made, women remain dramatically underrepresented in engineering fields. Over the years, an enormous amount of research attempted to understand the recruitment and retention of women in engineering. Retention issues include the "leak in the pipeline" phenomenon that refers to women leaving their academic programs or engineering jobs. Self Determination Theory (SDT) demonstrates that autonomy-relatedness and competence are essential psychological aspects that, when met, facilitate learning, motivation, and persistence. This work aims to understand if culture influences female students' levels of autonomy, relatedness, and competence to the extent that it could increase women in engineering fields. Several studies have focused on the relationship between culture and education to strengthen learners' educational level and motivation. This study presents the comparison of two land-grant institutions offering Engineering degrees. Both institutions are similar in size and academic offering in their Engineering Colleges while keeping different cultures. Montana State University (MSU), located in the Pacific Northwest of the United States, and the University of Puerto Rico - Mayagüez Campus (UPRM), a Hispanic Serving Institution located in the Caribbean. The differences in culture among institutions were analyzed and compared with the number of female students in engineering majors and their reported autonomy, relatedness, and competence levels. The ultimate goal of this research work is to understand how culture influences the number of females in engineering fields.

Keywords

Women in engineering, Culture, Self-Determination Theory, Recruitment

Introduction

Research studies discussed the concepts of diversity, inclusion, and equality broadly, but there is still discrimination and unfair treatment of minority groups, particularly with women in Engineering.[1] Significant research studies report on why women choose other types of careers [2], why they change to majors out of engineering or quit, [3] and why they do not get to practice the profession after completing an engineering degree.[4] The "leak in the pipeline" phenomenon explains women's tendency to quit their engineering jobs or studies.[5] Furthermore, females face many challenges as a result of their gender.[6] These themes are studied to overcome "machismo", traditional culture, and the false truth that women cannot pursue careers that men have traditionally dominated. With evidence demonstrating no gender differences for mathematical skills or other engineering-related abilities, [7] women feel less able to pursue these careers and even think they have many barriers and obstacles to achieve them.[8]

To understand social constructs that influence women, an increased interest in concepts as self-efficacy and the feel of competence have emerged in recent years.[9][10][11] Recent studies found concrete evidence that external factors in culture influence the current behavior towards females in engineering. This behavior often makes women feel they lack the capacity and abilities to pursue a career in engineering [12] or do not belong in engineering simply because of their

gender.[13] Thus, why do women feel less capable than men or think they cannot pursue an engineering career? A possible answer to this question lies in the basis of all social constructs, culture.

Culture is a group's identity, which shares traditions, norms, and beliefs and establishes roles.[14] The literature focuses on the effects of culture on the position and role of women in education and career.[15][16][17] It is uncertain whether culture is indeed an influencing factor in pursuing an engineering career.

Using the Self-Determination Theory's (SDT) basic psychological needs as a framework, we can potentially explain these questions. SDT explains human behavior from the psychological and motivation perspective and the development of personality. This theory focuses on the effects of socio-contextual factors and the consequences of satisfying basic psychological needs.[18]

This work assesses the relationship between culture and women's decision to pursue a career in engineering by examining their levels of competence, relatedness, and autonomy. The research objectives are to: (1) define potential differences between cultures, (2) analyze differences in female enrollment in engineering programs, and (3) comprehend the relationship of culture and females' levels of basic psychological needs.

The notion of culture underlying this study is broad. A comparative analysis is presented between two engineering colleges of similar size and different cultures to meet these goals. We applied the Six-Dimensions of Culture developed by Hofstede's [19] and the SDT's basic psychological needs [18] as the theoretical frameworks guiding this study.

Literature Review

Culture

Culture is an essential construct for the development and sense of belonging of a group or society. When culture is referred to as a "slippery and ubiquitous concept", multiple discussions emerge due to the plurality of meanings.[20][21] Culture is a social product, a conglomerate of ideas and beliefs defined by the nature and nurture of a social group taught generationally. It then becomes the identity of a group or society.

Based on the term identity emerged the idea of cultural identity. The interest in studying the concept of cultural identity has been increasing over the years. The main reason is the diversity and multiplicity of nationalities found in today's societies. In other words, our institutions are becoming multi-ethnic and multicultural.[22] Based on Social Identity Theory, there are two physical conditions: the individual identity and the collective identity.[23] Given that culture is a complex whole of social-contextual factors that help define and shape a person's identity as part of a social group, this work explores how the different cultural backgrounds relate to students' basic psychological needs.

Women in Engineering

Women's participation in engineering has increased significantly in the last decades. The Engineering by the Numbers report from the American Association for Engineering Education (ASEE) shows females' underrepresentation from bachelor's degrees to tenure-track faculty.[24]

Of all engineering degrees granted (BS, MS, and Ph.D.) in the US between 2009 and 2018, only 24%, on average, were earned by females. In 10 years, the rate of increment is less than 1% per year. Even though many women choose to pursue careers in engineering, some leave the field, and others prefer a different path. J. Hunt [25] explained why women leave science and engineering and introduced a new way to understand the exits of women. She also highlighted considerable literature that demonstrates the most significant factors that lead women to exit the career.

Historically and traditionally, women receive less support to consider careers in engineering than men.[26] These social factors that do not allow women to develop and reach their full potential in engineering careers are a common denominator in most cultures. The thought that women are not suitable to pursue engineering careers has nothing to do with their ability. There is scientific evidence showing that there are no differences in mathematical skills between genders.[27] Understanding how cultures see women can help us identify those elements that hinder their journey and access to these careers.

Basic Psychological Needs

Previous research shows that women in STEM programs do not feel that they have the capacity and abilities to pursue their careers; therefore, they underestimate their self-efficacy.[9][18][19] Self-efficacy refers to one's perception of whether one can accomplish certain goals or tasks.[28] Dell and Verhoven [29] explain that such perceptions impact people's decision-making regarding their self-confidence. Similar to culture and cultural identity, self-efficacy contributes to shaping who we are. The relationship between these factors and their impact on people's decisions should help understand how female students feel when deciding to pursue an engineering career. It will also help to identify what elements hinder their progress and which ones help them.

Self-Determination Theory (SDT) is centrally concerned with motivation without any influence and interference from external factors. Whether parents, teachers, coaches, or managers, all types of mentors are always searching for strategies to motivate their groups. People, in general, are moved by external factors such as rewards, good grades, and recognitions [29] and by intrinsic factors like interest, care, and values. The relationship between intrinsic and extrinsic motivations is the foundation of this theory develops.[30] SDT also focuses on how cultural and social factors influence people's will, performance, and initiative. As a result, it defines the three basic psychological needs: competence, relatedness, and autonomy.[30] The satisfaction of these basic needs allows providing the sustenance for intrinsic motivation and internalization.[29]

Competence refers to the self-perception of knowing a task and recognizing the ability to complete it. If a student realizes that they do not have enough knowledge or seem incapable of doing it, that will affect their motivation.[30]

Relatedness refers to whether a student recognizes and feels a sense of belonging towards a personal, academic, and professional community. When students think they are members of a group and have support, they can develop connections that allow them to grow. Thus, they develop good personal relationships. On the other hand, those who do not feel part of the group considered themselves outsiders and tended to isolate themselves, become demotivated, and feel indifferent.[30]

Autonomy refers to *"the degree to which individuals feel that they act on their own volition and choice".*[29] Students are empowered to make their own decisions when they feel comfortable in their environment and recognize that they have a voice, their opinions count, and their contributions are valued. When everything else happens, the demotivation factor reappears.

Methods

Data Collection

For the study of women's autonomy, relatedness, and competence in the context of different cultures, the research objectives are to (1) define potential differences between cultures, (2) analyze differences in female enrollment in engineering programs, and (3) comprehend the relationship of culture and females' levels of basic psychological needs. Specifically, we conducted a comparative study between two institutions to examine the differences and similarities between them. Both institutions Engineering Colleges are similar in size but different in terms of the predominant cultures and location. Accordingly, these institutions are Montana State University (MSU) and the University of Puerto Rico, Mayagüez Campus (UPRM).

During the Fall of 2019, MSU had 14,919 students enrolled, 3,048 students at the College of Engineering. On the other hand, at UPRM, 12,954 students enrolled, 4,036 at the College of Engineering. Students' populations at both institutions are homogenous: MSU has a predominantly white student population, while at UPRM, most of the students are Hispanic. Also, men are the predominant population within both Colleges of Engineering. At UPRM from 4,036 students 2,905 (72%) are men and at MSU from 3,048 students, 2,468 (81%) are men. One of the factors that motivate this research is that UPRM has a higher representation of women in engineering than MSU. Table 1 shows that the overall percentage of women in engineering at UPRM was 30.89% compared to 19.03% at MSU. Even so, women are still a minority at UPRM.

Table 1. Percentage of women students in all engineering departments by 2019.

Women in an Engineering Department	MSU	UPRM
Women in Civil Engineering	20.83%	26.57%
Women in Computer Engineering	10.17%	14.55%
Women in Electrical Engineering		12.31%
Women in Industrial Engineering	14.28%	45.08%
Women in Mechanical Engineering		19.07%
Women in Chemical Engineering	34.71%	54.02%
Women in All Engineering Departments	19.03%	30.89%

Theoretical Framework

It is vital to assess and comprehend the characteristics of the two social groups' cultural backgrounds to determine the relationship between culture and enrollment of females in engineering. We used Hofstede's Six Dimensions Model of National Culture (VSM) [9] to analyze differences between student populations at both institutions from diverse fields of study.

Hofstede's Six Dimensions of Culture

Culture can describe both concrete and abstract aspects.[31] Geert Hofstede [32] focuses on the abstract elements of culture and defines it as "the collective programming of the mind that distinguishes one group member from others". Based on his extensive studies of the influence of culture on workplace values, Hofstede developed the Six Dimensions of Culture Model (VSM). The dimensions are (1) power distance, (2) individualism vs. collectivism, (3) uncertainty

avoidance, (4) masculinity vs. femininity, (5) long-term orientation vs. short-term orientation, and (6) indulgence vs. restraint.[32]

Basic Psychological Need Satisfaction Scale (SDT)

Alongside Hofstede's VSM, we also used the Basic Psychological Need Satisfaction Scale. SDT focuses on the effects of socio-contextual factors and the satisfaction of the basic psychological needs of competence, relatedness, and autonomy.[18] The scale will show the levels of autonomy, relatedness, and competence in both institutions.

We administered our IRB-approved online questionnaire to all the undergraduate and graduate students from all disciplines at both institutions, using Qualtrics, during the 2019-2020 Spring semester and 2020-2021 Fall semester.

Data Analysis and Discussion of Results

A total of 968 undergraduate students participated from all majors in both institutions, 340 students from MSU and 628 from UPRM. Female student participation resulted in 606 students, which represent 62.6%, 205 at MSU (60.0%) and 401 at UPRM (63.8%). In our initial analysis, we applied the Six-Dimension of Culture Model to describe the cultural characteristics at both institutions. Specifically, we identified the differences and similarities between both student populations were assessed and compared them with the national scales (VSM). We also evaluated the scores by gender to determine differences and similarities among institutions. The following sections explain the results obtained from the analysis performed.

Power Distance Index (PDI)

The Power Distance Index (PDI) determines how those with less power accept or expect unequal power distribution. A high score in this index means that people strive for the distribution of power. VSM comprehensive scores for the US Mainland and PR are 40 and 68, respectively, with a mean score of 83.[19] Therefore PR is a hierarchical society with unequally distributed power where people accept that they are different. Lower scores in the US Mainland represent unequal roles among its members.

In our study, the PDI resulted in 3.53 and 10.48 for MSU and UPRM, respectively. When compared to national standards, our results showed significantly lower scores of PDI for both populations (Mainland and PR) that represent a change in the hierarchical characteristics of these populations.

For the PDI index, we found significant differences between male and female students for both institutions. UPRM female students reported a score of 14.53 versus a 3.71 for male students. At MSU, for female students, we obtained a score of 2.73 versus a 0.54 score for male students. Overall, at both institutions, females showed a higher PDI score but significantly higher at UPRM. Therefore, the analysis by gender indicated that both institutions follow the characteristics of non-hierarchical societies.

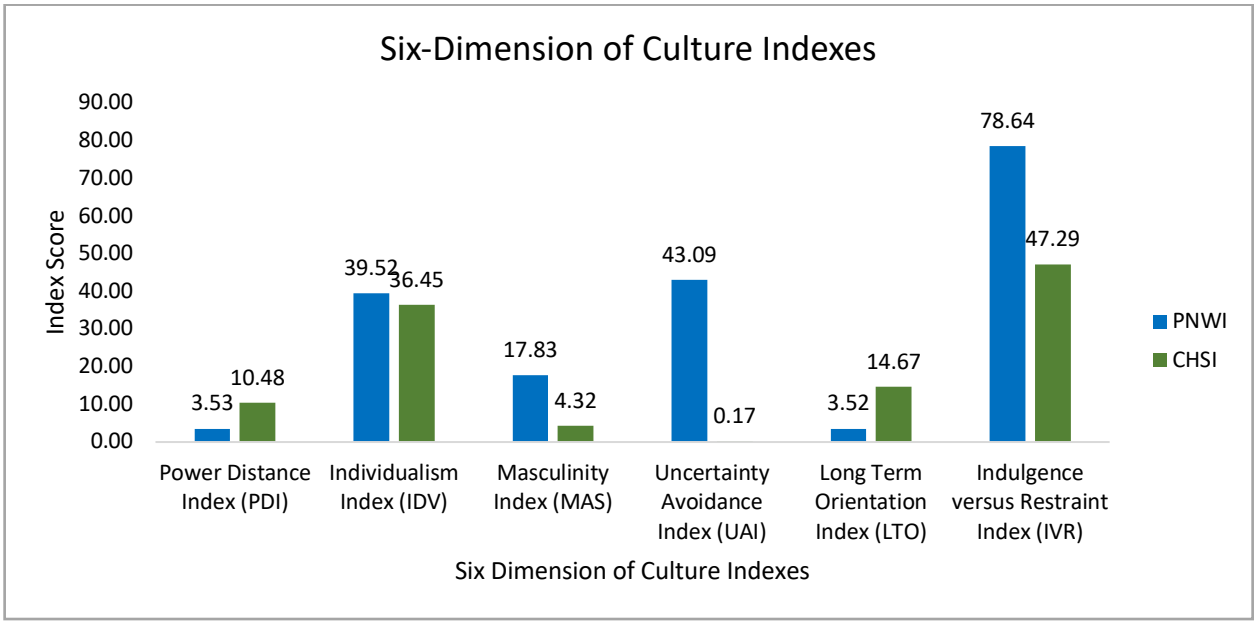

Figure 1. Results of the Six-Dimension of Culture Indexes in both MSU and UPRM.

Individualism Index (IDV)

The Individualism Index (IDV) identifies the relationship between individuals and the social group.[19] A low score in this index means that people live in groups to care for each other while providing support. VSM comprehensive scores for US Mainland and PR are 91 and 27, respectively, with a mean score of 60.33.[19]

MSU showed a score of 39.52 compared to 36.45 from UPRM. Therefore UPRM participants exhibited characteristics of a collectivist society in which people are born into groups that provide support and help to others in exchange for loyalty. Thus, the UPRM student population reflects a more ingrained sense of collectivism. Meanwhile, the mainland score of 91 represents an individualist society, where people expect to take care of themselves. On the contrary, MSU student population scores align with the characteristics of a more collectivist culture.

The analysis by gender revealed that female students reported a score lower than the general population at both institutions, with 33.98 for MSU and 36.31 for UPRM. For male students, we obtained a higher score of 46.40 and 37.18 for MSU and UPRM, respectively. Similar to what we found in the previous analysis, females at both institutions exhibited characteristics of a collectivist society.

Masculinity Index (MAS)

The Masculinity Index (MAS) refers to the distribution of values and roles by gender.[19] A high score in this index means that the society is more "masculine," and the dominant values will be heroism, competition, and success. Meanwhile, a low score means the culture is more "feminine," and cooperation, modesty, caring for the weak are some of the most important values. Based on VSM comprehensive scores, the mean score for this index was 70, and the US Mainland and PR score was 62 and 56, respectively.[19] Therefore it is expected for PR (56) to be a "masculine" society with "feminine" tendencies. On the other hand, the US Mainland (62) tends to be a

masculine society, where people are more ego-oriented and give more importance to success and show that success to others.

The MSU and UPRM student population obtained a score of 17.83 and 4.32, respectively. Therefore both societies are considered to have a "feminine" culture. The analysis by gender revealed lower scores between females and males at MSU and UPRM (Females at MSU=3.68, UPRM=1.97 vs. Males at MSU=8.37, UPRM=8.44). Therefore, we still concluded that both institutions exhibit characteristics of "feminine" culture.

Uncertainty Avoidance Index (UAI)

The Uncertainty Avoidance Index (UAI) refers to the degree of discomfort people show when facing situations, they lack control.[19] A high score in this index means that people feel threatened by ambiguous or unknown conditions, while a low score shows that people do not get altered by uncertainty and are not averse to taking risks. VSM comprehensive scores for the US Mainland and PR are 46 and 38, respectively, with a mean score of 91.67.[19] Therefore, both countries show tendencies of pragmatic societies, where people can make their plans but do not get altered or anxious if their plans change. Furthermore, community members do not averse to take risks and embrace change and new ideas without problems.

Our study showed a score of 43.09 for MSU versus a score of 0.17 for UPRM. Therefore, both student populations are very pragmatic; thus, they can embrace change and innovation. A lower index for UPRM means that UPRM students are more used to change, taking risks, and are more resilient than those at MSU. Therefore, it is expected a higher level of competence and autonomy, especially among female students. The analysis conducted by gender also showed that female students at MSU (15.98) and UPRM (10.36) could manage uncertainty much better than male students (MSU=43.09, UPRM=18.24).

Long Term Orientation Index (LTO)

The Long-Term Orientation Index (LTO) describes how societies maintain a relationship with their past while facing the future.[19] It is the only index that is strongly correlated with economic growth. Those societies with a low LTO score are categorized as normative societies, which means that these societies prefer to maintain traditions and norms and are very suspicious of societal change. Meanwhile, a high LTO score refers to a more pragmatic society in which people prepare for societal changes. VSM comprehensive scores are for US Mainland and PR 26 and 0, respectively, with a mean score of 58.5.[19] Since both societies have a low score, they are considered normative societies where members show great respect for traditions and norms, expect quick results, and do not prepare for the future.

Our results indicate that both populations are normative, with scores of 3.52 and 14.67 for MSU and UPRM, respectively. The LTO index for female students is higher than the general population at both institutions (MSU=13.61, UPRM=15.21). Although we categorized them as groups that give much importance to norms and traditions, we concluded that women tend to show more pragmatic characteristics than men (MSU=6.28, UPRM=13.53).

Indulgence versus Restraint Index (IVR)

The Indulgence versus Restraint Index (IVR) refers to the level of control people have over their impulses and desires.[19] A high score of this index means people have little or no control over their desires or impulses; this is called indulgence. Meanwhile, a low IVR score shows that the group members have control over their impulses or restraint. VSM comprehensive scores are 68 and 90 for US Mainland and PR, respectively, and a mean score of 53.5.[19] Therefore PR is expected to be an indulgent culture that exhibits a high level of gratification and enjoyment of life, following their impulses and desires. Thus they are very optimistic and give importance to leisure time.

Our analysis resulted in a score of 78.64 for MSU versus 47.29 for UPRM students. A comparison with comprehensive indexes revealed that MSU students have a higher tendency towards a more indulgent culture. UPRM students' scores differ significantly from comprehensive values (47 vs. 90). Therefore, students at UPRM are more restrained, exhibit great control over their impulses, are more disciplined, and do not give much importance to leisure time.

The analysis by gender revealed that MSU students, both female (82.02) and male (73.57), are more indulgent than those students at UPRM (female = 40.90, male = 57.96). Furthermore, female students at MSU showed more indulgent characteristics than male students. On the contrary, at UPRM, females showed to be more restrained than male students.

Summary

In summary, both institutions shared some aspects within their cultural characteristics in terms of culture but at different levels. Therefore, although we considered both institutions to exhibit the same attributes within an index, one group predominates significantly and adheres to those characteristics more than the other. There are inclinations for specific traits of the group's identity to influence the individual's identity; therefore, we wanted to determine the impact on the levels of autonomy, competence, and relatedness. We were interested in those indexes where we identified a significant difference between the student population and the general population, such as the IVR index.

Overall, the indexes showed significant differences between the general and student population, which we believe are due to two main factors: time and people. The values for the VSM comprehensive study were determined about 20 years ago, with participants from a different generation. Culture is a fundamental construct in the development of social and individual identities, and as the results show, identities are dynamic and complex; they change over time. Perhaps both social identities were significantly different in the past, but as time passes, those differences might be decreasing.

Basic Psychological Needs

The previous analysis allowed us to identify, define, and establish cultural differences in student populations at different levels. Cultural characteristics are critical for the development of social, individual, and engineering identities. The Basic Psychological Needs scale will allow a preliminary understanding of differences in autonomy, relatedness, and competence constructs related to engineering identity.

Our analysis revealed a statistical difference in only the competence component of the basic psychological needs for both populations (refer to Figure 2). Competence refers to the self-perception of knowing a task and recognizing the ability to complete it. If a student realizes that he or she does not have enough knowledge or seems incapable of completing a task, that will directly impact their motivation. Of the three basic psychological needs, competence is crucial as it is directly related to student motivation. This component is also part of the students' engineering identity, which, alongside interest and recognition, allows the healthy development of the student's sense of belonging with engineering. Therefore, it directly affects the number of students who decide to enroll in engineering programs.

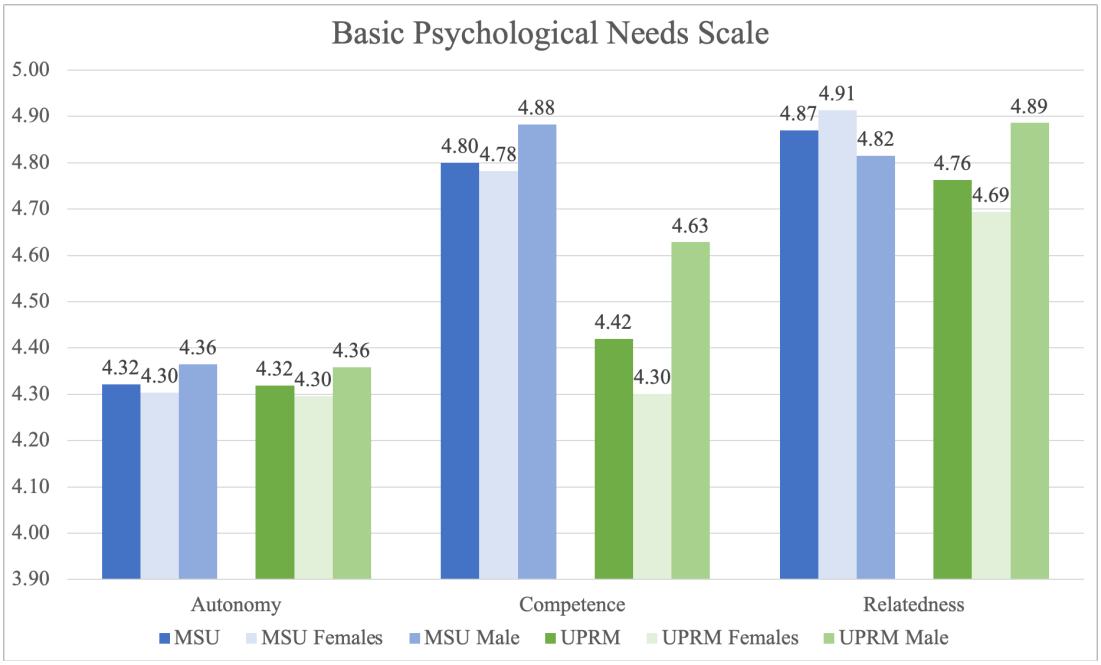

Figure 2. Results of the Basic Psychological Needs Scale in both institutions.

For this statistical analysis, we performed a t-test, where MSU obtained a level of 4.80 versus a 4.42 from UPRM (p-value = 0.409). We also identified significant differences between female students from both universities (p-value = 0.0001), whose values were 4.78 and 4.30, for MSU and UPRM, respectively. In addition, we compared male and female students from both institutions and found significant differences at UPRM (p-value = 0.004), where female students obtained an index of 4.30 and male students of 4.63. Meanwhile, MSU also acquired similar results (p-value = 0.449), where the female students got a value of 4.78 versus 4.88 for male students.

Furthermore, we established a relationship between the VSM dimension of cultures and the levels of basic psychological needs. Both MSU and UPRM populations have a low MAS index, indicating that teachers give equal attention to girls and boys, and there are minor gender differences in perceptual abilities.

In general, the comparison between female and male students at both institutions showed higher scores for the basic psychological needs among MSU students and between males and females. Therefore there is still a gender difference in perceptual abilities, specifically a more significant one among the UPRM student population.

Based on the UAI index, we expected that the UPRM students showed the highest levels of autonomy, but our results indicated no significant difference between institutions. In terms of IVR, UPRM students showed more restraint than indulgent characteristics compared to the PR VSM comprehensive scores. The main characteristic that exhibits this type of society is discipline. Perhaps, the low level of competence between female and male students in UPRM is explained by the fact that women tend to be "hard" on themselves and affect the way they feel about their own capabilities. The same thing can happen with the MSU population, but the difference in the competence level, in that case, is lower.

Conclusions

This work aims to assess the impact of culture and its effects on women's decision to pursue a career in engineering by examining their levels of competence, relatedness, and autonomy. The research objectives were to (1) Define potential differences between cultures and (2) Comprehend if culture has a relationship with females' levels of basic psychological needs. We conducted a comparative study between two land-grant institutions, MSU and UPRM, that proved differences in both populations' cultural characteristics and significant differences in competence level. Specifically, we evaluated the cultural factors using Hofstede's Six Dimensions of Culture Model: Distribution of Power (PDI), Masculinity versus Femininity (MAS), Uncertainty Avoidance (UAI), Collectivism vs. Individualism (IVC), Indulgence versus Restraint (IVR), and Long-term Orientation (LTO).

After collecting and analyzing data from 968 undergraduate students from both institutions, we determined that both student populations are more alike rather than different. Specifically, they have shown similarities when comparing them with the national scale. However, when examining both populations by gender, those similarities become scarce. From the six dimensions, the UPRM student population proves to be completely different from the national scale. Meanwhile, the MSU remains close to those on the national scale.

Furthermore, when examining these indexes by gender, there are some significant differences. For instance, females exhibited more hierarchical, individualistic, feminine, and pragmatic characteristics than male students. Female students at MSU also showed tendencies towards indulgence. On the contrary, female students at UPRM exhibited tendencies toward restraint. In general, there are cultural differences between student populations expected to influence the Basic Psychological Needs measures.

For the second part of the Basic Psychological Needs (autonomy, relatedness, and competence) analysis, we applied the Self-Determination Theory Center scale. Results showed that MSU students demonstrated higher levels of competence in general and among female students. Both institutions showed that male students have higher levels of competence, autonomy, and relatedness.

In conclusion, we found a pattern and tendency to correlate cultural characteristics and levels of competence, freedom, and relatedness. We need to conduct more analyses to identify and understand those characteristics with the different levels of self-determination.

Implications and Future Work

As part of future work, it would be necessary to examine the cultural characteristics and basic psychological needs by discipline and different groups within both institutions to determine significant differences. An example could be a comparison between females inside and outside of engineering. Another study area is to assess a larger scale questionnaire for culture evaluation to compare the states with the national scale to confirm whether the current indexes are correct and whether the societies have changed. Finally, developing a qualitative analysis study could help understand and explain why there was no significant difference in cultural dimensions of why the levels of competence are different between females and males. As part of this research, the following steps involve measuring students' engineering identity and examining the comparison between cultural characteristics and identity.

Acknowledgments

The authors will like to thank the National Science Foundation (NSF) and the Puerto Rico Louis Stokes Alliance for Minority Participation (PR-LSAMP) Bridge to the Doctorate Program Cohort XIII (Grant Number: HDR-1906130) for the support given to Nolgie Oquendo for the completion of this work. The authors will also like to thank Yinaris Guzmán Cruz, Andrea K. Rivera Castro, Andrea P. Sepúlveda Vargas, and Alejandro Rodríguez Natal for their help with collecting and pre-processing the data.

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