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WIP: Characterizing Personal Cultural Orientations of First-Year Engineering Students by Latent Profile Analysis: A Person-Centered Approach

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Abstract
This work-in-progress research paper adopts a person-centered approach to explore latent cultural profiles of first-year engineering (FYE) students, contributing to culture-centered engineering education research. Despite several previous works investigating the role of culture on engineering student experiences and learning, there is still a need to better characterize the cultural profiles of engineering students and professionals, especially with the proper application of established frameworks and models. Grounded in Hofstede's cultural value model, this work seeks to characterize personal cultural orientation (PCO) profiles of FYE students via latent profile analysis. We surveyed over 1,700 FYE students at a large Midwestern University with Sharma's 2010 PCO instrument. Data were processed via latent profile analysis with three steps: 1) conducting confirmatory factor analysis; 2) clustering data using weighted factor loadings and evaluating potential results via model fit statistics; and 3) interpreting the final chosen result based on PCO profiles and demographic data. The findings reveal five distinct cultural profiles existing among FYE students, where four cultural dimensions (gender equality, social inequality, interdependence, and power) exhibit the largest variations to distinguish profiles. This work not only expands our understanding of FYE students from a cultural perspective but also lays a foundation for advancing culture-based scholarship in engineering education, fostering equitable and inclusive practices.

Keywords: latent profile analysis, person-centered approach, cultural orientation, culture

Introduction

The engineering education community has made significant contributions to culture-related scholarship, such as funds of knowledge [1]–[3], funds of identity [4], community culture wealth [5]–[7], and culturally relevant/response pedagogy [8]–[11]. The rising attention to asset-based pedagogy and research perspective responds to the educational disparity existing in engineering education, particularly for students of Latiné, Black, Native American, and first-generation backgrounds – including those with disabilities [12], [13]. Particularly, we contend that asset-based paradigm shifts are helpful in ensuring full recognition of students' unique experiences, identities, backgrounds, and embedded cultures. Engineering education in the United States has been historically influenced by cultural norms, such as Whiteness, masculinity, ableism, etc. [14], which might be incongruent with those cultures valued by minoritized engineering students.

Further, to broaden participation in engineering, we must be able to value and characterize diversity in a meaningful way [15], [16], where cultural diversity is deemed as part of the work. Numerous scholars lamented the lack of consideration and even the danger of using demographic variables, particularly race, in analytical models of quantitative research [17]. This is because these categories are neither natural nor given [18], and standard demographic variables like race and gender are laden with sociopolitical implications that complicate the interpretation of the results. In fact, using race as a causal variable has been criticized as a "form of racial reasoning" [19, p. 131]. The recent trend of person-centered approach advocacy promotes using analytical techniques that unpack the *latent diversity* within the sample, extending beyond the typical demographic variables that tend to be used as groupings. [20]–[23]. The core tenet of person-centered approaches centers on investigating how latent traits, perceptions, or mindsets are related across individuals to form a basis for further analysis, including probing the underlying demographic information [22].

Beyond responding to the call to adopt new epistemological perspectives on quantitative methods to unpack latent diversity, there is also a lack of in-depth investigation into engineering personnel's cultural orientation. Prior work highlighted the three dominant ideologies representing engineering culture: technical/social dualism, depoliticization, and meritocracy at the societal level [14]. Other related studies collected PCO data from individual engineering students also exist, providing evidence that 1) students from different engineering majors might perceive cultural dimension(s) at different levels [24], and 2) a subset of cultural orientations had significant correlations with a crucial team dynamic construct, psychological safety [25]. Therefore, we contend that understanding the dominant and non-dominant cultural profiles perpetuating among engineering students has great potential to inform strategies to address educational disparity. There is also a need to reveal the patterns of cultural orientations embedded in engineering students with an established framework to pave the foundation for studies advancing culture-related scholarship.

In this regard, this work asks the following research question: **What are first-year engineering students' personal cultural orientation (PCO) characteristics, as identified by latent profile analysis?**

Literature Review

Culture has been defined as the "collective programming of the mind which distinguishes the members of one human group from another" [26, p. 25]. Despite culture emerging from social groups, individuals embrace cultures and subcultures that most resonate with them and form personal cultural orientations, which function and regulate their perceptions, cognitions, and, ultimately, behaviors [27]. Hofstede's cultural value model [26] presents a useful theoretical foundation for understanding culture. The cultural value model is composed of five cultural dimensions: individualism-collectivism, power distance, uncertainty avoidance, masculinity-femininity, and long-term-short-term orientation (interested readers could refer to the reference for the detailed explanations for the connotation for each dimension) [26]. However, the creation of such a cultural value model was rooted in country-level analysis, which can be considered a potential ecological fallacy [28]–[30]. Accordingly, the model has been criticized for not being applicable to lower-level unit analysis. Additionally, Hofstede conceptualizes cultural dimensions as continua, where, for instance, one must be high for individualism and low for collectivism orientation; this conceptualization has been repeatedly challenged [28]–[33]. Therefore, in this work, we followed Sharma's personal cultural orientation (PCO) model and instrument, which we believe best aligns with the purpose of this study [34]. Sharma expanded each of Hofstede's cultural value dimensions into independent pairs, including independence (IND), interdependence (INT), power (POW), social inequality (IEQ), risk aversion (RSK), ambiguity intolerance (AMB), masculinity (MAS), gender equality (GEQ), tradition (TRD), and prudence (PRU). For instance, power refers to the extent to which individuals accept differences in the power wielded by various members of a unit, e.g., a teacher has the highest authority within a class. Due to page limitation, we provide the full definitions for all PCO dimensions from Sharma's work [34] in Table 2 in the Appendix.

Methods

We administered Sharma's instrument of PCO [34] to a cohort of 1752 FYE students at a large, public Midwestern university in the 2022 Fall semester. Aligned with the research design by Homero and Cruz [24], we only surveyed the first eight of ten dimensions of Sharma's instrument that are most relevant in introductory engineering courses with team-based learning settings. Each dimension was measured by four items with a seven-point Likert scale.

In the data preprocessing stage, we first performed Little's test [35] to rule out if the data was missing completely at random (MCAR). The test returned a p-value greater than 0.1, meaning the data cannot be assumed as MCAR. Given the result and the consideration of a low level of missing data at the individual level rather than item or construct level (i.e., $< 7\%$), we decided to list-wise delete all data entries with missing data and retain only data with complete responses. After data cleaning, our database contained responses from 1630 students.

Latent profile analysis was conducted via the tidyLPA program in R [36]. With the ability to interface with MPlus [37], a popular software platform for structural equation modeling, we ran the LPA with various model parameterizations to determine which model best fits the data. This approach allowed us to conduct a holistic examination to select the best-fitted model representing the student's PCO. We also determined the best fit for the number of profiles by using AIC [38], BIC [39], bootstrap likelihood ratio test (BLRT) [40], and entropy. Models with lower AIC and BIC are considered to have better fit. If the p-value of the BLRT is below 0.05, the profile is considered statistically different from the proceeding model. Profiles that had an entropy value lower than 0.80 were excluded. We also looked at the minimum number of students in the profile (n_{min}) to avoid low representation – we set the threshold to 32, which is about 2% of the total sample size for this study and is considered within best practices for running an LPA [41].

Preliminary Results

After running the analysis, we determined that the best model for the data was one that assumed equal variances and equal covariances in the analytical modeling. The finally selected model contained five distinct cultural profiles among FYE students (n = 1630), which best fitted the data evaluated based on the model fit criterion. The profiles and their descriptions are provided in Table 1. A breakdown of the profiles by their scores is also provided in Figure 1, where the numbering is in the same order shown in Table 1.

Table 1. Overview of the Five Personal Cultural Orientation Profiles

Profile Number	Profile Name	Profile Description	*n (%)*
1	Moderate all	Students reported **moderate** scores in ALL cultural dimensions	51 (3)
2	High Gender Equality, Low Power & Social Inequality	Students reported higher scores in gender equality, but lower in power and social inequality	149 (9)
3	High Gender Equality & Interdependence, Low Social Inequality	Students reported higher scores in gender equality and interdependence, but lower in social inequality	1240 (76)
4	High Interdependence, Low Social Inequality	Students reported higher interdependence and lower social inequality	138 (8)
5	Moderately High All	Students reported moderately high scores in ALL cultural dimensions	62 (3)

***Note**. Due to rounding, the percentage does not sum up to 100%.*

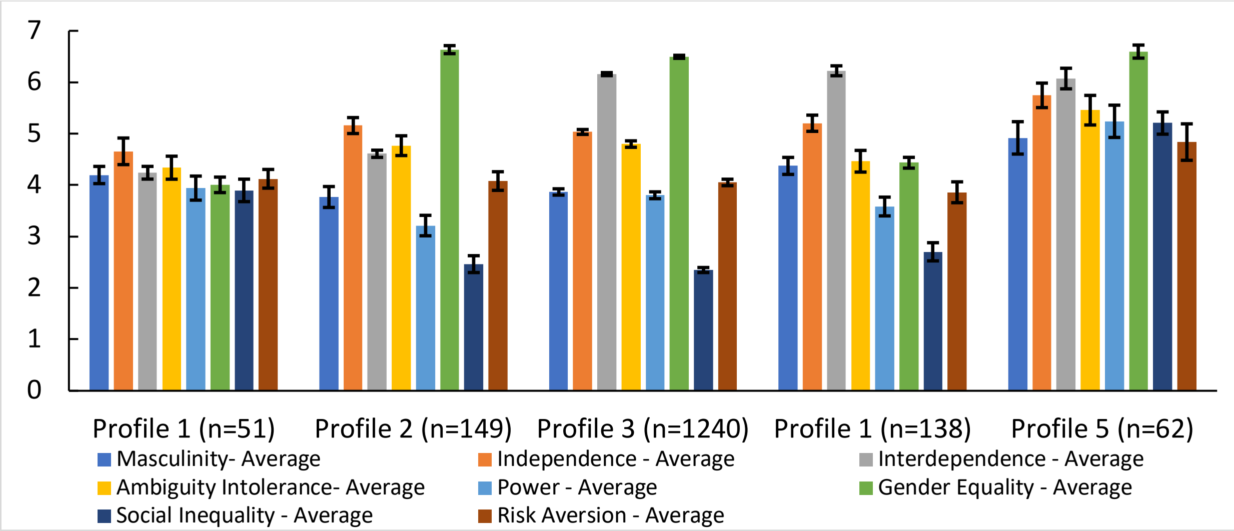

Figure 1. FYE Student Personal Cultural Orientation Profile Breakdown with Mean Scores

The results from the latent profile analysis reveal significant variability in the cultural orientations of FYE students. Most students (76%) fall into Profile 3 (high gender equality & interdependence, low social inequality); we interpret the profile indicates a strong preference for collaboration, inclusivity, and equitable interactions with peers and others. This trend suggests that values of teamwork and equality are internalized into the cultural worldview of most engineering students. Smaller groups emphasize different aspects. Profile 2 (high gender equality, lower power & social inequality) highlights equity but also strongly rejects the differences in power held by members within a unit. In contrast, Profile 4 (high interdependence, low social inequality) shows collaboration might be a central, dominant theme for students with this cultural profile. Two minority profiles, Profile 1 (moderate all) and Profile 5 (moderately high all), exhibit balanced or heightened tendencies across all cultural dimensions without a strong emphasis on a specific factor.

From Figure 1, we can also visually notice four cultural dimensions with large variations: gender equality, social inequality, interdependence, and power. Profiles 2, 3, and 5 demonstrate relatively high scores on gender equality, highlighting its centrality to the cultural values of engineering students. These scores align with the broader societal efforts to promote diversity and inclusivity in STEM education [42]–[44]. Social inequality, in contrast, shows consistently low scores in Profiles 2, 3, and 4, indicating a widespread rejection of social equality as normal. Interdependence is particularly pronounced in Profiles 3, 4, and 5, reflecting a strong inclination toward teamwork, collective achievement, and prioritizing group goals over individual ones. The dimension of power varies significantly, with Profiles 2 and 3 demonstrating low scores, reflecting resistance to hierarchical structures, while Profiles 1 and 5 show moderate acceptance of power differences.

Concluding Remarks and Future Work

This work showcases the existence and differences in five distinct cultural orientation profiles among FYE students, highlighting the heterogeneity within the student body. The dominance of Profile 3 (high gender equality & interdependence, low social inequality) suggests that most engineering students value collaboration and inclusion, emphasizing the continuous need to foster a collaborative, equitable learning environment. Notably, this work provides additional perspective for instructors when adopting culturally responsive and relevant pedagogy. Specifically, instructors might want to tailor their teaching to address the variability in students' cultural orientations, particularly regarding differential perceptions of power, social inequality, and gender equality. However, this work only got student self-reported data from one school.

For research implications, this work paves the foundation for researchers with a new angle to investigate how culture might play a role in other pertinent constructs, such as team dynamics, engineering identity, sense of belonging, learning experiences, and more. For instance, one might investigate whether students who hold a cultural profile tend to have stronger engineering identities. Furthermore, adopting latent profile analysis also sets an example of person-centered approaches to unpack latent diversity in the student population.

In the future, we will further display the demographic distribution of students in each cultural profile to check if a cultural profile has a dominant representation in terms of a particular demographic group. If so, we will conduct follow-up studies to examine the potential convergence of students' personal cultural orientations with their national culture.

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Appendix

Table 2. Definitions of Personal Cultural Orientation Dimension Definitions [34]

Dimension	Definition
Independence	"A personal cultural orientation associated with acting independently, a strong self-concept, a sense of freedom, autonomy, and personal achievement (p. 790)"
Interdependence	"a personal cultural orientations associated with acting as a part of one or more in-groups, a strong group identity, a sense of belongingness, reliance on others, giving importance to group-goals over own individual goals, and collective achievement (p. 790)"
Power	"the extent to which individuals accept differences in the power wielded by various members in any organization (p. 790)"
Social Inequality	"the degree of inequality among people in a society which the individual accepts as normal (p. 790)"
Risk Aversion	"the extent to which people are reluctant to take risk or make risky decisions (p. 791)"
Ambiguity Intolerance	"the degree to which people can tolerate ambiguity and uncertain situations (p. 791)"
Masculinity	"represents the expression of assertiveness, self-confidence, aggression, and ambition (p. 791)"
Gender Equality	"the extent to which people perceive men and women as equal in terms of social roles, capabilities, rights, and responsibilities (p. 791)"
Tradition	"represents respect for traditional values including hard work, non-materialism, benevolence, social consciousness, morality, and respect for one's heritage (p. 792)"
Prudence	"represents planning, perseverance, thrift, and future orientation (p. 790)"