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Team dynamics and cultural competency in a first-year engineering classroom

Dr. Jutshi Agarwal, University of Cincinnati

Jutshi Agarwal is a Post Doctoral Fellow with the Department of Engineering and Computng Education at the University of Cincinnati. She has a Doctoral degrree in Engineering Education and a Master's degree in Aerospace Engineering from University of Cincinnati, and a Bachelor's degree in Aerospace Engineering from SRM University, India. Her research areas of interest are graduate student professional development for a career in academia, preparing future faculty, and using AI tools to solve non-traditional problems in engineering education.

Dr. P.K. Imbrie, University of Cincinnati

P.K. Imbrie is the Head and Professor of the Department of Engineering Education and a Professor in the Department of Aerospace Engineering and Engineering Mechanics University of Cincinnati. He received his B.S., M.S. and Ph.D. degrees in Aerospace Engineering from Texas A&M University. He is an advocate for research-based approaches to engineering education, curricular reform, and student retention. Imbrie conducts both traditional, as well as educational research in experimental mechanics, piezospectroscopic techniques, epistemologies, assessment, and modeling of student learning, student success, student team effectiveness, and global competencies He helped establish the scholarly foundation for engineering education as an academic discipline through lead authorship of the landmark 2006 JEE special reports ”The National Engineering Education Research Colloquies” and ”The Research Agenda for the New Discipline of Engineering Education.” He has a passion for designing state-of-the-art learning spaces. While at Purdue University, Imbrie co-led the creation of the First-Year Engineering Program's Ideas to Innovation (i2i) Learning Laboratory, a design-oriented facility that engages students in team-based, socially relevant projects. While at Texas A&M University Imbrie co-led the design of a 525,000 square foot state-of-the-art engineering education focused facility; the largest educational building in the state. His expertise in educational pedagogy, student learning, and teaching has impacted thousands of students at the universities for which he has been associated. Imbrie is nationally recognized for his work in active/collaborative learning pedagogies, teaming and student success modeling. His engineering education leadership has produced fundamental changes in the way students are educated around the world.

Imbrie has been a member of ASEE since 2000 and has been actively involved with the Society in various capacities. He has served in multiple leadership roles in the ERM and FPD divisions, including: ERM board of directors (2002-2004), program chair for ERM (2005 and 2009), ERM program chair for Frontiers in Education (FIE) (2004), FIE Steering Committee ERM representative (2003-2009), as well as program chair (2016) and division chair (2016-17) for FPD. He has also served on two ASEE advisory committees.

Team dynamics and cultural competency in a first-year engineering classroom

Abstract

This research paper is motivated by the observation that team-based pedagogies are becoming more ubiquitous in engineering classrooms. ABET's requirement for engineering graduates to demonstrate a capability to work effectively in diverse teams and the industry's increasing reliance on intra- and inter-departmental teams has contributed significantly to this. In particular, engineers of today are expected to work effectively in global teams with members from different backgrounds including country of origin, race, gender, and first language. In this regard, the ability to discern the similarities and differences between team members and using those to cohesively work together has become crucial. In academic environments too, students face diverse teams as the demographics of engineering colleges evolves to be more inclusive.

When assigning teams in classrooms, evidence has pointed instructors to avoid student-selected teams or random-assignment and rely on criteria-based team assignments instead. Traditionally, instructors have chosen various criteria like academic performance, skills, prior knowledge in the topic area, demographics, personality types, learning preferences, and even schedules to divide students into homogeneous or heterogeneous teams. Lack of cultural competency and awareness, however, can often lead to team dysfunction in academic settings when students face difficulty in interacting with each other due to language and cultural differences. Some studies have retroactively investigated the cultural competency of members in teams formed using traditional criteria. But, the literature shows little to no evidence on the impact of using cultural competency as one of the criteria for creating teams in engineering classrooms. This research attempts to fill this gap and examine team dynamics as a result of this. The research question investigated in this study is: how do team dynamics differ in teams that have been formed to represent homogeneity and heterogeneity in cultural competency respectively, in addition to traditional criteria?

The study is situated in a first-year introductory engineering course at a large, public, midwestern, R1 university with a class size of about 1450 students divided into about 27 sections. Student teams are usually formed in the beginning of the semester based on prior knowledge of programming and computing skills in addition to other demographics. In an experimental design, an additional criterion of cultural competency was added where sections of the course had teams with: homogeneous, heterogeneous, and random (control) cultural competency. Cultural competency was examined using the Miville-Guzman Universality-Diversity Scale short form (M-GUDS-S) which measures a single construct of Universal- diversity orientation (UDO) with three factors. Team dynamics were measured using instruments of team effectiveness at the end of the semester. The paper discusses the evidence of reliability and validity of the self-reported instruments with an analysis of differences in the team dynamics of sections based on homogeneous, heterogeneous, and control group of M-GUDs score. The study discusses the implications of assessing the cultural competencies of students in the context of teamwork in engineering classrooms and how different cultural competencies of students in a team impacts teamwork and in turn student learning.

Introduction

Globalization has increased the importance of foreign markets and international commerce making the American workforce more globally interdependent. This has necessitated that engineers of today work in collaborative environments to solve problems in global contexts. Undergraduate engineering education needs to focus on training engineers who can work in effective teams whose members are diverse in geographic location, origin, skills, and culture [1], [2], [3], [4]. This prompted the ABET to change the EC2000 criterion of learning outcomes, "*understand the impact of engineering solutions in a global, economic, environmental, and societal context*" to the 2022-23 criteria with multiple elaborate learning outcomes under Criterion 3:

"2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.

3. an ability to communicate effectively with a range of audiences.

5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives" [5].

These learning outcomes have prompted engineering programs to employ collaborative pedagogies like team-based learning in the classroom. With such pedagogies, engineering students are learning in more diverse environments. Furthermore, engineering classrooms and campuses are also gradually becoming more diverse in race, ethnicity and culture. While such diversity has had a positive impact on their cognitive development, it has also become critical that students are trained in cross-cultural competencies like identifying their biases and increasing awareness of diversity issues [6]. Effective members in global team settings have the ability to know and understand how people from different parts of the world interact, value, and perceive the same aspects differently [1].

Cultural competency and M-GUDS

In this context, the term global competency or cultural competency is often used as a broad descriptor. Cultural competency has been described to have multiple dimensions of cognitive (related to knowledge), behavioral, and attitudinal (affective or emotional) [4]. There are several instruments developed to measure cultural competency in different contexts and dimensions. One such instrument is the Miville-Guzman Universality-Diversity Scale (M-GUDS) which measures the cultural competency using the construct Universal-Diverse Orientation (UDO) – "an attitude of awareness and acceptance of both the similarities and differences among people" [7]. Originally developed as 45-item scale, but later shortened to 15-items (M-GUDS-S) measure UDO in three factors –

Diversity of contact (behavioral): interest in participating in diverse and internationally focused activities of social and cultural nature;
Relativistic Appreciation (cognitive): appreciation of similarities and differences in people;
Comfort with difference *(affective)*: comfort level with individuals from diverse backgrounds.

Initially developed for the field of psychology, M-GUDS-S has been applied in engineering education settings by several researchers with different aims. Jeisek et al. measured undergraduate engineering students' cultural competency to find that participation in global engineering programs, gender, and prior international experiences are significant factors that contribute to UDO and its factors [4]. In a different study of first-year engineering students, women and underrepresented minorities showed higher UDO scores; and age was a significant factor for international students [7]. In a post-graduate engineering context, similar trends were observed by Main and their colleagues [8] including the knowledge of a foreign language to be a significant factor among doctoral students.

Cultural competency has been used as a construct in evaluating efficacies of interventions such as new models of study abroad programs [9], courses as a substitute for study abroad programs [10], and to investigate differences between different demographic groups of engineers [11], [12]. Cultural competency, however, is very important in the context of engineering teams but there is little to no literature between their relationship. Moreover, our literature search did not reveal any studies that used cultural competency as a criteria for team forming and investigated the functioning of engineering teams, whether in educational settings or in the industry. This research aims to fill this gap. Using a team-based first year course as the educational setting, different strategies of using cultural competencies as team forming criteria were used. The goal was to examine how team dynamics differ in teams where members have different relative cultural competencies. The research question investigated in this study is: *how do team dynamics differ in teams that have been formed to represent homogeneity and heterogeneity in cultural competency respectively, in addition to traditional criteria?* The following sections describe the methods in detail followed by our findings.

Methods

Educational Setting

The study is based in the College of Engineering and Applied Sciences at a large, public, Midwestern, R1 university. Study sample were students enrolled in the first of a two-semester first-year introductory engineering course sequence. The course enrolls about 1300-1500 students from all engineering majors every Fall, who are divided into 24-28 sections each with the class sized of 40-72. The course involves a flipped-classroom pedagogy and covers content focused on engineering design thinking and applications of engineering fundamentals including algorithmic thinking using multiple computational tools. Students work in teams during in-class activities and on multiple projects throughout the semester.

Team forming

Different educational settings use different team forming criteria when implementing team-based pedagogies. These criteria vary from institution to institution, course to course, and instructor to instructor. Self-selected or random team assignment are being avoided based on evidence-based practices, shifting the criteria for team assignment by instructors to be more intentional. Following similar trends, at the beginning of the fall semester, students enrolled in the course answer a survey that investigates their prior experiences and competencies with programming, excel, and other computer skills. These responses are combined with demographical data including sex, race, engineering living learning community participation. This data is used to assign students to teams of four, with a minimal number of 3-member teams in each section. Team assignment is done with the aim of establishing uniform heterogeneity [13] where each section has a wide range of skills *within* teams, which are also balanced *between* teams. It is also ensured that each team has at least one student with prior experience in programming. Women and underrepresented minorities are assigned in teams so that they are not isolated.

In fall 2022, when this study took place, in addition to the traditional team forming criteria, the students were administered the M-GUDS-S instrument to investigate their UDO. They were then assigned into quartiles based on these scores. In an experimental set-up, some sections were assigned teams to maintain homogeneity of UDO score within teams as an additional criteria, some sections had all teams where the UDO scores were spread heterogeneously within teams, while the third category of sections had random UDO assignment within teams. This meant that the third category of sections only followed the traditional criteria for team assignments.

Data Collection

As mentioned in the previous sections, students enrolled in the course answered a beginning of the semester survey that was used to assign them into semester-long teams. Every semester, the course also administers an end-of-semester survey which investigates several aspects of the course. One section in this survey is the team effectiveness scale developed by Imbrie et al. [16]. The team effectiveness scale has a four-factor structure measuring *learning*, *interdependency*, *goal setting*, and *potency*. Responses are collected on 7-point Likert scale with 0 = strongly disagree to 6 = strongly agree. The 26-items scale contains two items that are reverse coded and used for validating responses by comparing lack of polarity on responses to other items. In this study, only the three factors of *interdependency* (the team member's perception of the cooperation among team members used to accomplish tasks, 9 items), *goal setting* (the team member's perception of the degree to which the team set outcome goals and sub-goals to accomplish tasks, 5 items), and *potency* (the team member's perception of the degree to which team can reach their goals, 5 items) were relevant to measuring team dynamics in the context of cultural competency, so team dynamics was analyzed from responses to 19 items loading onto these factors.

Data cleaning and analysis

In Fall 2022, N = 1471 (Male = 1178 (80%), Female = 293 (20%); White = 1049(71%)) students enrolled in the course in 26 sections. Out of the 13 instructors teaching the course, one instructor formed the teams in all three of their sections using different criteria than mentioned above. Students belonging to these sections were removed from analysis. Students in 8 sections were assigned teams using homogeneous and heterogeneous criteria, while 7 sections were random under the UDO criterion.

At the end of the semester, only 850 (57.7 %) students answered the team effectiveness instrument. When validating the responses, 68 data points were removed using the two reverse coded validity items when they matched the responses on all other items. Of the remaining data, 67 came from the three sections that did not participate in the same team forming criteria as mentioned above, so these were removed. The sample size for further analysis was n = 715 (Male = 548 (76.64%), Female = 167(23.36%), White = 527(73.7%)).

For the data analysis, reliability and validity analyses were conducted for the team effectiveness scale. The responses were validated for a 3-factor model using a CFA analysis and Cronbach's alpha was calculated for internal consistency reliability of each factor of team effectiveness including the sum score for total team effectiveness. Following this, each of the factor scores and the sum team effectiveness scores were tested for differences between the random, homogeneous, and heterogeneous. This was done at the student level where individual student responses were treated as a unit of comparison for n = 715. Future work will build on findings from this study, where differences will be investigated based on team as a unit of analysis.

Results

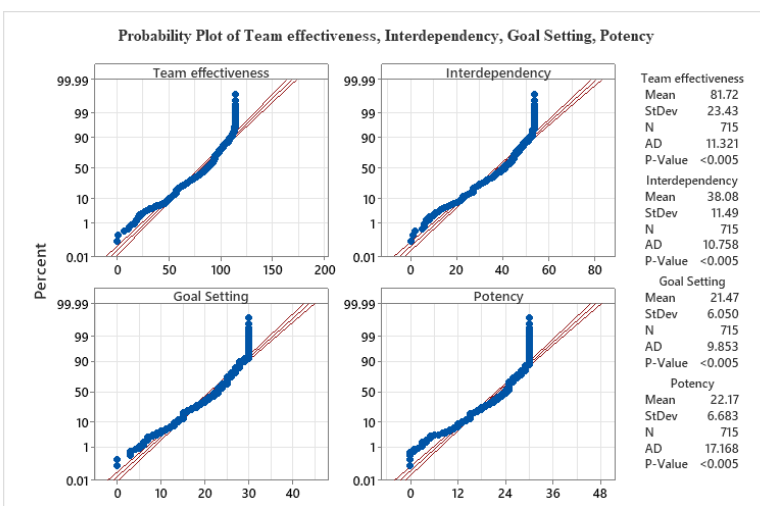
Reliability and validity

The team effectiveness scale was tested for a 3-factor CFA model with 19 items. With a sample size, n = 715, results for the best fit model included $\chi^2(149) = 752.838$, p = 0.000. The model did not fit based on chi-square as a measure which is expected in large sample sizes. Approximate fit indices were investigated and found to be CFI = 0.998; TLI = 0.997; RMSEA = 0.075, SRMR = 0.039. The standards for good fit are CFI and TLI greater than 0.95 [14]. For RMSEA, cut off for approximate fit is between 0.05 and 0.08 with <0.05 as a good fit. For SRMR values < 0.08 are to be expected. Based on these values, the data showed a good fit for a three-factor model.

Reliability analysis for the 19-item model showed α(interdependency) = 0.93, α(goal setting) = 0.87, and α(potency) = 0.93, and α(team effectiveness) = 0.97 all evidence of high internal consistency reliability (> 0.7 or 0.8, [15]).

Differences in team effectiveness between groups with different teaming criteria

To answer the research question of whether team dynamics differs in teams formed using random, homogeneous, and heterogeneous distribution of UDO, differences in team effectiveness scores of students belonging to each group of teaming criteria was investigated. Each of the factor sum scores and team effectiveness sum scores were first tested for normality. It was observed that all variables violated the assumption for normality so Kruskal-Wallis test for differences between groups had to be substituted for one-way ANOVA (see fig below). Descriptive statistics for each of the four variables of interest are shown in Table 1 below. Results of individual Kruskal-Wallis tests have also been summarized in Table 2.



As is evidenced by the bolded p-value in Table 2, only goal-setting scores showed significant differences for students assigned in teams using different team criteria of UDO at the significance level of 0.05.

Table 1: Descriptive Statistics for Kruskal-Wallis tests

Teaming criteria	N	Median			
		Team Effectiveness	Interdependency	Goal Setting	Potency
Random	222	85	41	22	24
Homogeneous	238	86	40	22.5	24
Heterogeneous	255	90	42	24	25
Overall	715				

Discussion

Preliminary investigations show inconclusive results. Team effectiveness as a construct of team dynamics did not show significant differences with differences in team forming criteria. However, one of the sub-constructs of team effectiveness, goal setting had significant differences based on different team groupings. Other factors of team effectiveness did not show significant results. While major findings are contradictory to our expectations, significant differences in 1 factor support the hypothesis that differences in cultural competencies between team members can impact team dynamics. However, further investigation is needed to confirm this hypothesis. The contradictory results in significant differences is evidence to support the need for further research in this area.

Table 2: Summary of Kruskal-Wallis tests

Null hypothesis	H_0: All medians are equal			
Alternative hypothesis	H_1: At least one median is different			
	Team Effectiveness	**Interdependency**	**Goal Setting**	**Potency**
DF	2	2	**2**	2
H- value	4.29	3.36	**6.46**	4.56
p-value	0.117	0.186	**0.040**	0.102

As a preliminary step to explain the contradictory findings, we investigated the distribution of team effectiveness within teams and observed that members of the same team had vastly diverse perceptions of their team dynamics. This was evident by the polarity in each factor scores of members of the same team. Such polarity was seen across a majority of the team. This points to the need of investigation in multiple directions. Firstly, it can be suggested that perceptions of the same team differed for team members because their expectations and goals from the teams were different. For instance a student who expected high cohesion with team members may perceive a moderately effective team as low while student with low expectations may rate it higher. Secondly, the fidelity and interpretation of team effectiveness scale can potentially be a cause too. Prior experience by authors using the same instrument had suggested a need for training students in team science and evaluations of team functioning. With the lack of such training, students' rating of their team effectiveness may not be devoid of confounding factors. Thirdly, only 850 out of 1471 students answered the team effectiveness survey at the end of the semester. This resulted in data missing at the teams-as-a-unit level, hindering further investigation of within and between team dynamics.

The findings in this study also have limitations at the team forming stage. While UDO scores were used a criteria in different ways, it wasn't the only criteria for team forming. Traditional criteria used in the course were given priority and UDO was used as a last criteria in forming teams. This could have significant implications to the interpretation of findings. A truly experimental setup was not feasible for a course offered at such a large scale. Furthermore, team effectiveness can also vary with different factors in the course such as different instructors, prior experience of students with teamwork, self-efficacy in course content, personality difference, and team player disposition. These confounding factors need to be controlled for in future investigations to find generalizable results.

This study is a first-step in examining how differences in cultural competency of members in a team effects team effectiveness. With the significant dearth of literature in this area, there is little room for informed hypotheses. Future work is planned to implement experimental designs in smaller groups where lack of missing data and feasibility of interventions do not hinder the research.

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Appendix A: Team effectiveness Scale

INTERDEPENDENCY

My team collaborated effectively to complete our assignments.

My contributions to the team were appreciated by each team member.

I had confidence in each team member to contribute their fair share of what was required.

My team used a process/method (e.g., code of cooperation) to hold each member accountable.

At any particular time, I knew each team member's role, so I knew what to expect from them.

An outside observer would have concluded our team had an effective process to complete our assignments.

Team members arrived on time to team meetings.

Team members were prepared for team meetings.

My teammates displayed appropriate interpersonal skills when conflict arose.

GOAL SETTING

My team used clear, long term goals to complete tasks.

My team reflected upon its goals in order to plan for future work.

My team made use of incremental goals (i.e., we set short term goals) in order to complete course assignments on time.

My input was used to set our team goals.

This team helped me accomplish my individual goals for this course.

POTENCY

My team was confident in its ability to overcome adversity (e.g., interpersonal conflict, assignments).

I feel a sense of accomplishment in my team's ability to work together.

This team gave me confidence in the ability of teamwork to solve problems.

My team had the collective abilities (e.g., communication, interpersonal, technical) to accomplish course assignments.

I was confident that our team produced acceptable solutions to course assignments.

VALIDITY

Overall, I thought being on this team was a very negative experience.

Our team did not function well as a team; we did not establish any process to hold one another accountable nor did I ever know what individuals were responsible for.