WIP: Evaluating The Effectiveness of Diversity on Teams' Performance in Engineering Education

Prof. Amr Hassan, University of Pittsburgh

Dr. Amr Hassan (also know as Amr Mahmoud) received his B.Sc. degree in Electronics and Electrical Communications Engineering and the M.Sc degree in Engineering Physics from Cairo University, Egypt, in 2011 and 2015, respectively. He earned his PhD in Com

Dr. Mohamed A. S. Zaghloul,

Mohamed A. S. Zaghloul was born in Cairo, Egypt, in 1987. He received his B.Sc. degree in Electronics and Electrical Communications Engineering in 2009, and his M.Sc. degree in Engineering Physics in 2012, both from the Faculty of Engineering at Cairo University. In 2019, he received his PhD from the Department of Electrical and Computer Engineering at the University of Pittsburgh, where he is currently working as an Assistant Professor. His research interests are engineering education, and in the area of optics; he specializes in developing optical fiber-based sensors for monitoring harsh environments.

Dr. Irene Mena, University of Pittsburgh

Irene B. Mena has a B.S. and M.S. in industrial engineering, and a Ph.D. in engineering education. She has experience teaching programming, design, entrepreneurship, and sustainability topics, and is the Director of the First-Year Engineering Program at the University of Pittsburgh.

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Abstract

Diversity and inclusion are recognized as essential components of contemporary engineering education, fostering enriched learning environments, and driving innovation. This paper examines the impact of diversity on team performance within engineering education, with a focus on the team's diversity composition and its influence on academic outcomes. A First-Year Engineering Program course under the school hosting this study was investigated, where students were divided into diverse teams, assembled based on factors including gender, race, ethnicity, and background using CATME Team-Maker tool. Research questions focus on the comparative performance of diverse and non-diverse teams, optimal team composition for maximizing performance, and the potential for developing universal metrics for assessing team effectiveness in engineering education.

Evaluation methods include quantitative analysis correlating team grades with diversity metrics and qualitative assessments through student surveys, providing insights into the impact of diversity on team dynamics and academic achievement.

1. Introduction

Diversity and inclusion are fundamental cornerstones in modern engineering education. Adopting a wide range of backgrounds, experiences, and perspectives enhances the learning environment and fosters innovation. Inclusive engineering programs ensure that students from various ethnicities, genders, and socioeconomic backgrounds have equal opportunities to excel. According to a recent NSF report [1] about diversity in STEM, the number of students from underrepresented minority groups who have earned a bachelor's degree in engineering has increased by 28.5% between 2011 and 2020. Specifically, the number of women who earned a bachelor's degree in engineering increased from 18.8% to 23.8%, between 2011 and 2020, respectively [1]. The number of bachelor's degrees in engineering awarded to Hispanic or Latino students jumped from 9.2% to 14% between the same two years. This increase in enrollment and degrees awarded for minority groups should be matched with a more inclusive and suitable learning environment for all students.

In engineering schools, typically students work in teams throughout the whole undergraduate period, tackling different problems and project types. In order to ensure that students get the most beneficial experience of being part of a team and the maximum team performance, team formation needs to take different factors into account, with how diverse the team is being a very important one [2]. Acquiring teamwork skills is crucial for all engineers because the engineering field relies heavily on collaboration [3]. These skills are highly valued by educational accreditation agencies [4] and employers worldwide due to its recognized importance [3]. While acquiring teamwork skills is an educational process that takes time to develop, it certainly can be enhanced by the culture and diversity of the team that students are in [5]. However, it's not always an easy task to be in such diverse teams, as it may have broader impacts on team dynamics, discipline, and communications [6].

In this work-in-progress, the authors will evaluate the effectiveness of diversity on teams' performance in engineering education at the school hosting this study for a First-Year Engineering Program (FYP) course. While many studies can be found in the literature under this topic, as will be discussed in the following section, to the authors' best knowledge, the following research questions have not been proposed before. The authors are trying to answer the following research questions: 1) do diverse teams perform better than non-diverse teams in engineering education, 2) is there a team composition, in terms of how diverse the team is, that maximizes the team performance, and 3) ultimately, could the results obtained from this study drive a much bigger question of can we come up with a universal metric for engineering educators to measure teams' performance.

For the course under investigation, students get divided into teams at the beginning of the semester and work on a semester-long project, consisting of various assignments throughout the semester, with the same team. The authors used CATME to divide the students into teams, taking into consideration different forms of diversity, such as gender, race, ethnicity, and background. While we end up with many diverse teams, some teams still end up being non-diverse. Evaluation and assessment of this work will be done in two different aspects, quantitative and qualitative. For the earlier, team grades for the different project assignments will be collected, analyzed, and correlated with how diverse the team is. For the qualitative assessment, students were surveyed multiple times throughout the semester, using CATME Peer Evaluation, to capture their perspectives about their experience on being part of a diverse (or non-diverse) team (IRB approval was obtained).

The rest of the paper is organized as follows: Section two mentions previous work on this topic and how this work is different. Section three introduces the course under investigation, the details of implementing the study, and the analysis of the data. Section four provides the assessment methods used and a discussion on the obtained results, while section five concludes the paper.

2. Background, Previous Work, and Motivation

Literature is full of different studies revolving around the main subject of this work: team diversity in education. The most related ones will be mentioned in this section to highlight how our study fits in. Bielefeldt [7] had explored the relationship between cognitive diversity within teams and their performance in an environmental engineering course, specifically focusing on personality types. Despite efforts to form diverse teams, there was no significant improvement in project grades, although student satisfaction increased when teams were cognitively diverse. However, Bielefeldt added that the presence of a coordinator personality type seemed to enhance team performance, suggesting potential benefits for future research in engineering team dynamics [7].

Pucha et al. [8] explores the influence of diverse teams and socio-cultural factors on student learning in a freshman engineering design course. The authors discussed the impact of diversity on students' self-perceived improvement and the role of socio-cultural aspects in student design work products by employing diverse team formation and Sustainable Design Goals (SDG)-focused team projects to address these issues. Results indicate increased student engagement and understanding of their cultural capital and diversity's role in creative product design [8]. They also presented a framework that offers insights into fostering inclusive learning environments in engineering education through project-based learning and socio-cultural approaches.

Finally, in 2015, Jimenez-Useche et al. [9] examined the impact of increasing international student enrollment, particularly in U.S. engineering programs, on team dynamics. Teams were formed of 3-4 people at maximum using CATME Team-Maker [10] and 59% of them were multicultural. Findings reveal that as the proportion of non-U.S. students increases in teams, there are lower levels of cohesiveness, higher conflict, and decreased satisfaction [9]. Cultural and language differences significantly influence team dynamics, affecting perceptions of interdependence, conflict, and satisfaction.

The authors were motivated to pursue this study because most of the literature work they found only tackles diversity from one aspect. In this work-in-progress, we will study different dimensions of diversity, such as race, gender, and ethnicity, and how teams with different compositions of each interact and perform.

3. Course Format

The course investigated under this study is named ENGR 0011: Introduction to Engineering Analysis, which is part of the First-Year Engineering Program (FYP) at the school hosting this study. The data collected was from two different sections of the same course and offered during the Fall 2022 semester. The number of students for both sections totaled 144 students and were divided into teams of max three students during the second week of the semester. The instructors used CATME® Team-Maker [10, 11] activity to help in efficiently forming the teams. The activity leads by surveying the students about many things, including: their weekly schedule, time zone, race, gender, leadership skills, commuting time to campus, among other things. Then, when the instructors form the teams, each item on the survey has a scale from -5 to +5, where -5 is "group dissimilar" and 5 is "group similar". CATME® then uses these values provided to form the team and try to maximize the lowest score when forming them. It's worth mentioning here that the instructors left all the scales at their default value, except for race and gender where they changed the scale to +2 to not outnumber minority students in a group. Depending on the student population in each class, sometimes we end up with teams of only two students.

The course topics are divided into two main categories: Engineering Analysis using Excel and Introduction to Design and Entrepreneurship (DE). For the DE part, students learn about the design process, and they apply it on a semester-long project related to sustainability, where they need to come up with a design and make a prototype for it that tackles the sustainability-related problems around the campus. The data collected for this study is drawn from the DE part, where students work in their teams towards their assigned problem. The DE assignments are divided into eight homework assignments spread throughout the semester, where five of them are team assignments (submitted as a team and all the students get the same grade) and three are individual assignments. These five assignments serve as the basis for the quantitative analysis in section 4.2 below. The DE assignments were worth 20% of the students' final grade.

4. Assessment Methods and Results

The number of teams totaled 51 between both class sections under this study. Most of the teams had three students, with four only having two students due to dropouts and withdrawals. For the results shown below, the teams were labeled one of four labels: Fully Diverse (FD), Somewhat Diverse (SD), Non-Diverse (ND), and Unknown (U). The classification criterion is shown in Table 1 below. The results from the team making activity mentioned above were used for the purpose of this classification.

As shown in Table 1, two thirds of the teams were at least SD, which emphasizes how diverse engineering schools are becoming. If one or more team members didn't specify their gender or race/ethnicity, the whole team was classified as U, even if there was diversity already between the other team members.

Table 1: Diversity Labels and Classification Criterion

Label	Classification Criterion	Number of Teams
Fully Diverse (FD)	Differences in BOTH race and gender	9
Somewhat Diverse (SD)	Differences in EITHER race or gender	25
Non-Diverse (ND)	Same gender, same race	9
Unknown (U)	Student did not indicate race or gender	8

4.1. Qualitative Analysis

During Fall 2022 semester, students were asked to fill in three CATME BARS® (PEER-EVALUATION) [12, 13] surveys, with the last one being at the end of the semester, when they finish all their team projects. These surveys were part of their regular course work and were worth 5% of their final grade, so they were not offered for the sole purpose of this study. For the limited space of this paper, the survey questions will not be included, but they can be accessed easily through the CATME® website [12] as the authors used the default set of questions.

The qualitative data in this paper consists of open-ended responses provided by students in their peer evaluations. As part of these evaluations, students are expected to complete peer-to-peer comments, in which they provide comments to each teammate, as well as write comments about themselves [14]. The instructor then releases these comments so that they are visible to the entire team via CATME®.

This paper looks at the peer-to-peer comments submitted by students as part of their third peer evaluation assignment, completed at the end of the semester. Data analysis consisted of open coding, in which codes and categories emerged from the data [15].

The codes mostly fell under one of two main categories: positive comments and negative comments. Table 2 below provides a list of the codes that fell under each category, as well as an example comment for each one.

Table 2: Different Categories of Student Responses with Examples for Each One

	EXAMPLE
POSITIVE COMMENTS	
About teammate's work, work ethic, and/or personality	"He was very good about getting the most out of everyone. Very committed to creating a good product for every assignment."
About entire team's work and/or team work ethic	"I feel that the work has been evenly and fairly distributed across all teams and that there have been no issues whatsoever in our team."
About self and/or self-work ethic	"I believe that I worked really well this semester and completed tasks on time and done according to the given instructions."

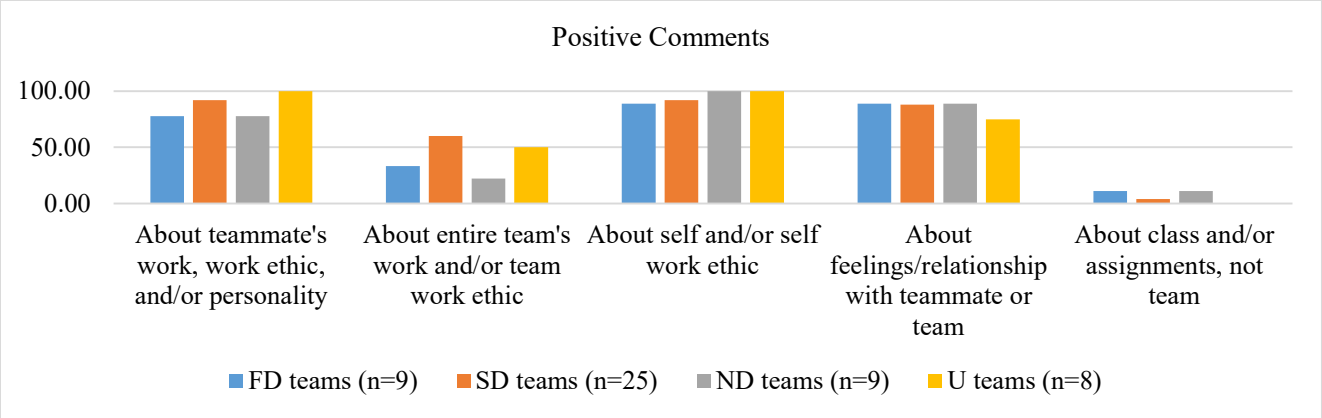
About feelings/relationship with teammate or team	"...it was a pleasure and blessing to get such a team."
About class and/or assignments, not team	"I learned a lot about excel and design in this class and enjoyed developing this environmental problem project."
NEGATIVE COMMENTS	
For/about teammate	"Does not participate in the group very much."
For/about self	"…I wish I had applied myself slightly more at times and was less nervous about brainstorming and putting my ideas out there."
For/about entire team	"...I would prefer greater communication [within the team]."
NONE	
No comments, or nothing to say	"n/a"

The results of open coding students' answers for Positive (Negative) comments are depicted in Fig. 1(a) (Fig. 1(b)). The y-axis represents the percentage of teams, by diversity classification, that mentioned each code sub-category, referenced to the total number of teams under that diversity classification. It's worth noting that some comments may contribute to two code sub-categories or more, under each main category, which may lead to a specific team being counted twice or more. For the Positive category, the percentage of SD and FD teams were at least as equal as those of ND teams for all the subcategories, except for "*About self and/or self-work ethic*". On the other hand, the percentage of FD teams with negative comments was at max 11.11% and always significantly less than those of ND teams, for all subcategories (see Fig. 1 (b)). However, this is not the case for the percentage of SD teams with negative comments, when compared to ND teams. The authors revert this result to the fact that the number of SD teams was approximately triple that of ND teams and therefore the probability of having teams with negative comments is higher. In addition, all the percentages of the SD teams were below 15% for all the categories, except for "*for/about self*", which is not directly related to team dynamics and/or performance.

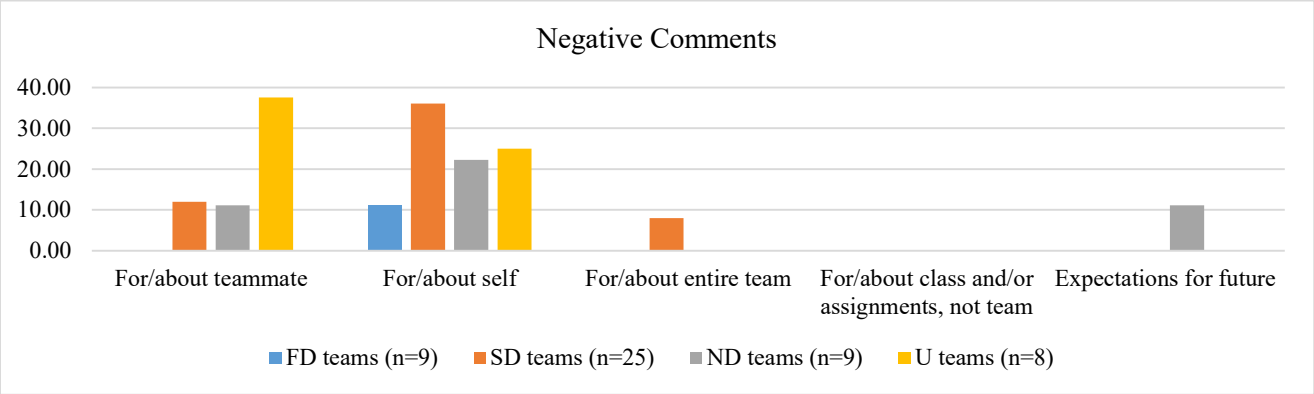
These results suggest that diverse teams might tend to work better and be more likely to have positive comments about their teammates, entire team, and self-work ethic, when compared with non-diverse teams.

4.2. Quantitative Analysis

For the quantitative analysis, the average grade for all team-based assignments for the DE part of this course was calculated and the results are shown in Table 2. For the purpose of this analysis, the categories "*Positive*" and "*Non-Positive*" were derived from the categories used in section 4.1. Only teams with all positive comments were considered under "*Positive*" and any team with at least one negative comment was considered "*Non-Positive*". This would ensure that each team contributed only to a single category. The number of teams for each team diversity classification under each category is shown in Table 2 (between parentheses). As depicted by Table 1, the average grades for diverse teams (FD and SD) were higher than ND teams by 4.57% which shows that diverse teams performed better, on average, than non-diverse teams. Moreover, for each diversity classification, the "*Positive*" category tends to do better than "*Non-Positive*" counterpart, except for the FD classification. However, the authors think this is due to the fact that all the FD teams were categorized as *Positive*, except one, so this is likely not of significant statistical importance.



(a)



(b)

Figure 1: Open Coding Results of Students' Responses. (a) shows the Positive Category, while (b) shows the Negative one.

Table 2: Average Team Assignments Grade for different team diversity classification and categories.

	Positive (count)	**Non-Positive (count)**	**Avg by Team Diversity Classification**
FD	95.18 (8)	100 (1)	**95.71**
SD	98.03 (12)	96.36 (13)	**97.16**
ND	94.77 (5)	89.03 (4)	**92.22**
U	99.12 (3)	96.89 (5)	**97.73**
Avg by Category	**96.75**	**95.36**	

5. Summary and Conclusions

In this WIP study, we investigated the effect of diversity on teams' dynamics and performance for engineering students, in a FYP course. Survey data collected from the students about team dynamics and performance were analyzed qualitatively, while average grades for team assignments were analyzed quantitatively. While most of the results suggest that diverse teams tend to perform better, in terms of

both grades and team harmony and dynamics, there are many factors to be investigated and considered for future subsequent studies. For example, the authors want to investigate more and see if the code subcategory named "*about self or self-work ethic*" is maybe related to gender and/or race, and if minority students tend to feel pressured and need to perform better if they were outnumbered in a team.

In addition, the authors want to expand this study to include more sections of the same course that are already taught at the university hosting this study to further support the results obtained here. Last, but not least, the authors want to analyze students' performance in individual assignments in this course and see if it can be related to them being part of diverse/non-diverse teams.

Subsequent following studies will ultimately aim to develop a universal metric for gaging the performance of engineering students' teams, to be used by engineering educators.

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