WIP: A Comprehensive Study on The Effect of Diversity Composition on Engineering Teams' Dynamics

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Abstract

This work-in-progress study investigates the impact of team diversity on interpersonal interactions and overall harmony within engineering teams in undergraduate education. Diversity, encompassing gender, race, ethnicity, and background, is increasingly recognized as essential for fostering innovation and creativity. However, its implications on team dynamics, such as psychological safety, interpersonal cohesiveness, satisfaction, and conflict, remain underexplored. Focusing on an introductory engineering analysis course offered to first-year students, the study utilizes the CATME tool for team formation and peer evaluation. By analyzing survey results and feedback, the research examines how diverse versus non-diverse team compositions influence teamwork experiences. Building on prior work suggesting enhanced performance in diverse teams, this study extends the scope to address team harmony and interpersonal relationships. Results are expected to provide actionable insights into optimizing team composition in engineering education, enhancing student experiences, and fostering inclusive learning environments.

1. Introduction

In today's engineering education, diversity and inclusion play a pivotal role in shaping a progressive and innovative academic landscape. Embracing individuals from different cultural, social, and economic backgrounds enriches classroom interactions and drives creativity. Engineering programs aim to provide students of all genders, ethnicities, and socioeconomic statuses with the resources and opportunities needed to thrive. A recent NSF report [1] highlights significant strides in diversity within STEM fields. For instance, from 2011 to 2020, bachelor's degrees in engineering earned by underrepresented minority groups rose by 28.5%, while the proportion of women earning engineering degrees grew by 26.2% [1]. Similarly, the percentage of Hispanic or Latino students obtaining engineering degrees rose by more than 50% over the same period. These promising trends emphasize the need to create more supportive and inclusive learning environments that cater to the diverse needs of all students.

In engineering programs, students frequently collaborate in teams throughout their undergraduate studies, addressing various projects and challenges. Effective team formation, especially with an emphasis on diversity, is crucial for improving both team efficiency and the educational experience [2]. These abilities are highly valued by accreditation organizations [3] and employers worldwide [4], though honing them requires time. A team's culture and diversity can greatly enhance this developmental process [5], but participating in diverse teams can also pose difficulties, such as effects on communication, discipline, and interpersonal dynamics [6].

In this work-in-progress, the authors will study the effect of team members' diversification on the teams' performance and inter-personal interactions. The study will be looking at two compositions of diversity: gender and race, and their effect on different aspects of team dynamics, including: 1) interpersonal cohesiveness, 2) psychological safety, 3) team satisfaction, and 4) team conflict. The course investigated will be an introductory engineering analysis course offered to first-year engineering students in the First-Year Program (FYP) at the school hosting this study. The authors plan mainly to answer the following

research question: *does the diversity composition of the team affect the overall team harmony and how team members interact together?*

In this course, students get divided into teams of three at the beginning of the semester and work on a semester-long project, with the same team, until the end of the semester. The authors used CATME to divide the students into teams, taking into consideration different diversity aspects, 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 quantitively, using CATME Peer Evaluation, to capture the students' opinions about their experience in being part of diverse/non-diverse teams (IRB approval was obtained).

This work is a continuation of a preliminary study that was published before [7] on the effect of student diversity on engineering teams' performance. While that study suggests that diverse teams tend to perform better on graded assignments, this work will extend the investigation to include the harmony and inter-person interactions of team members within diverse versus non-diverse teams.

The remainder of the paper is structured as follows: Section 2 reviews prior research on this topic and highlights how this study differs. Section 3 describes the course being examined, outlines the study's implementation, and details the data analysis process. Section 4 discusses the assessment methods employed and analyzes the results, while Section 5 summarizes and concludes the paper.

2. Background, Previous Work, and Motivation

Numerous studies, nationally and internationally, can be found in the literature studying the effect of team diversity on team members' psychological safety and team cohesiveness. Diegmann et al. [8] introduced a model to explore how diversity, psychological safety, and social agile practices influence resilience and performance in agile software development. By integrating organizational psychology and agile system research, their study aimed to deepen understanding of team-level dynamics in this field [8]. According to the authors, in dynamic environments, team resilience—the ability to recover from challenges—is crucial. Research in organizational psychology highlights the importance of team diversity and psychological safety in enhancing performance, particularly as teams grow more diverse.

On the other hand, Lee et al. [9] investigated the effect of gender diversity on managing status conflict within teams. The authors used an evolutionary perspective to examine team psychological safety as a key mechanism and gender diversity as a boundary condition for understanding how status conflict affects creativity. Through multimethod studies across Korean and North American samples, the findings provide new theoretical and practical insights into the combined effects of status conflict and gender diversity on psychological safety and team creativity [9]. The authors discovered that although status conflict undermines team creativity by creating a psychologically unsafe environment, its negative effects are more effectively mitigated in gender-diverse teams compared to gender-homogeneous ones.

Finally, Verwijs et al. [10] studied team diversity and its role in increasing conflicts within software teams. The authors explored how diversity in gender, age, role, and culture influences team effectiveness and conflict, with psychological safety as a potential moderator. Using data from 1118 participants across 161 teams, the findings revealed that age diversity enhanced team effectiveness, while gender diversity heightened relational conflict [10]. Psychological safety directly improved teamwork and reduced conflict but did not moderate the diversity-effectiveness link.

The authors will expand on the literature work by studying two compositions of diversity: gender and race, and their effect on different aspects of team dynamics, including: 1) interpersonal cohesiveness, 2) psychological safety, 3) team satisfaction, and 4) team conflict, in undergraduate engineering education.

3. Course Format

The course investigated under this study is named ENGR 0011: Introduction to Engineering Analysis, which is part of the FYP at the school hosting this study. The data collected was from six different sections of the same course, all offered during the Fall 2022 semester. More than 430 students were in these six sections, and they were divided into teams of max three students during the second week of the semester. The instructors utilized the CATME® Team-Maker [11, 12] tool to streamline the process of forming teams. This activity involved surveying students on various factors, such as their weekly schedules, time zones, commuting times, leadership abilities, gender, race, and more. Each survey item was assigned a scale ranging from -5 ("group dissimilar") to +5 ("group similar"). CATME® used these inputs to create teams, aiming to maximize the lowest score during team formation. Notably, the instructors kept the default scale values for all items except for race and gender, where they adjusted the scale to +2 to prevent minority students from being outnumbered in a group. Depending on the class composition, some teams ended up consisting of only two students.

The course content is divided into two primary areas: Engineering Analysis using Excel and an Introduction to Design and Entrepreneurship (DE). In the DE section, students explore the design process and apply it to a semester-long sustainability project. This project requires students to develop a design and create a prototype addressing sustainability challenges on campus. The data used in this study is derived from the DE component, where students collaborate in teams to tackle their assigned problems. The nature of these assignments obligates the students to hold group meetings regularly, brainstorm many ideas for the design/prototype and narrow them down into one choice, use of the makerspace to develop a low-resolution prototype, and organize a group presentation about their project. In addition, for every assignment, students must equally divide the tasks among them and report "who-did-what" to us. The DE coursework includes eight assignments distributed throughout the semester, with five being team-based (submitted collectively with all team members receiving the same grade) and three being individual assignments. Throughout the semester, the students completed three CATME BARS® (PEER-EVALUATION) [13, 14] 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. Due to space constraints, only the sections of the survey that were analyzed were summarized, but the full survey can be easily accessed on the CATME® website [13], as the default set of questions was used.

4. Assessment Methods and Results

A total of 148 teams were formed across the six sections included in this study. While most teams consisted of three students, eight teams had only two members due to student dropouts and withdrawals. For the analysis presented below, teams were categorized into one of four groups: Fully Diverse (FD), Somewhat Diverse (SD), Non-Diverse (ND), and Unknown (U), based on the classification criteria outlined in Table 1. This classification utilized data from the previously mentioned team formation activity. As shown in Table 1, 48% of the teams were categorized as SD, and 20% as FD, highlighting the increasing diversity in engineering schools, whereas about 18% were ND. Teams were labeled as U

if one or more members did not specify their gender or race, and the remaining members shared the same gender and race. Since the U teams are a very small fraction of all the teams studied (2.4%), the authors decided not to include them in the data analysis.

Table 1: Diversity Labels and Classification Criterion

Label	Classification Criterion	Number of Teams
Fully Diverse (FD)	Differences in BOTH race and gender	30
Somewhat Diverse (SD)	Differences in EITHER race or gender	64
Non-Diverse (ND)	Same gender, same race	27
Unknown (U)	Students did not indicate race or gender	3

The following subsections will include the results of the data collected from five different sections of the third CATME BARS® (PEER-EVALUATION) [13, 14] survey the students took. All the graphs are generated using the "box-and-whisker" style, where the mean is represented by the × mark, the median is the bar inside the box, the min and max values are the lower and upper dashes respectively, the bottom of the box is the 1st quartile, and the top of the box is the 3rd quartile.

4.1. Team Satisfaction

For this part of the survey, students were asked three questions about their level of satisfaction with being part of their designated team. These questions are: Q1) I am satisfied with my present teammates, Q2) I am pleased with the way my teammates and I work together, and Q3) I am very satisfied with working in this team. Each one of these questions was answered with a 5-point Likert scale, with 1 being "completely dissatisfied" and 5 being "completely satisfied". The average score of the three questions was calculated for each student, then averaged over the whole team. The results of this final average per team versus the diversity category are shown in Fig. 1. As can be seen in the graph, team satisfaction for ND teams is only 6.8% (0.3 points) higher than those of the diverse teams.
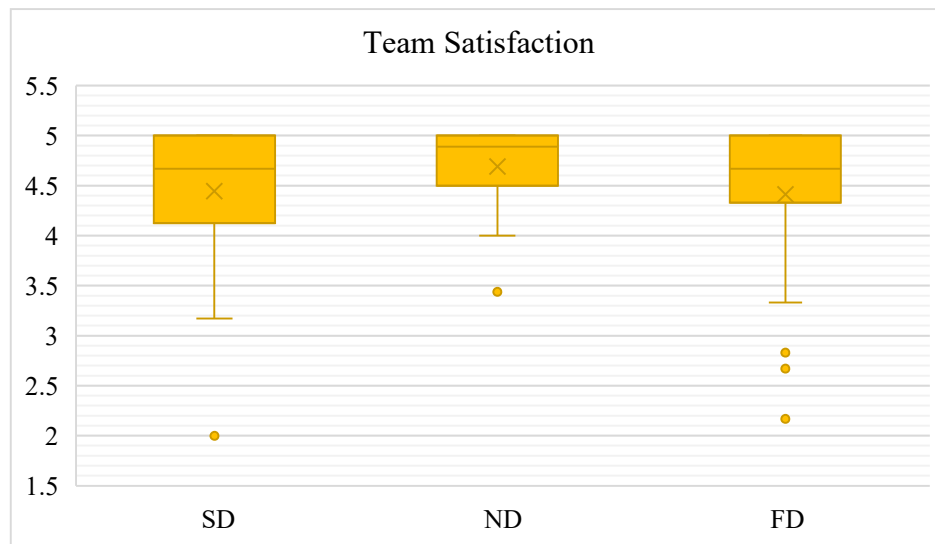

Figure 1: The average score of the team satisfactions questions per each diversity category.

4.2. Team Dynamics

In the survey, students get to rate themselves (on a scale from 1 to 5) and their teammates on five different aspects of being part of a team: 1) **C**ontributing to the Team's Work, 2) **I**nteracting with Teammates, 3) **K**eeping the Team on Track, 4) **E**xpecting Quality, and 5) **H**aving Related Knowledge, Skills, and Abilities. For the purpose of the following analysis, we are going to refer to these five aspects as CIKEH. The average score for each aspect of the CIKEH was calculated first by student, then calculated per team. Fig. 2 shows the average score per diversity category for each aspect of the CIKEH. Only slight differences exist between ND teams and any diverse team, which suggests that the diversity aspect of the team may not have either a positive or a negative impact on the team dynamics.
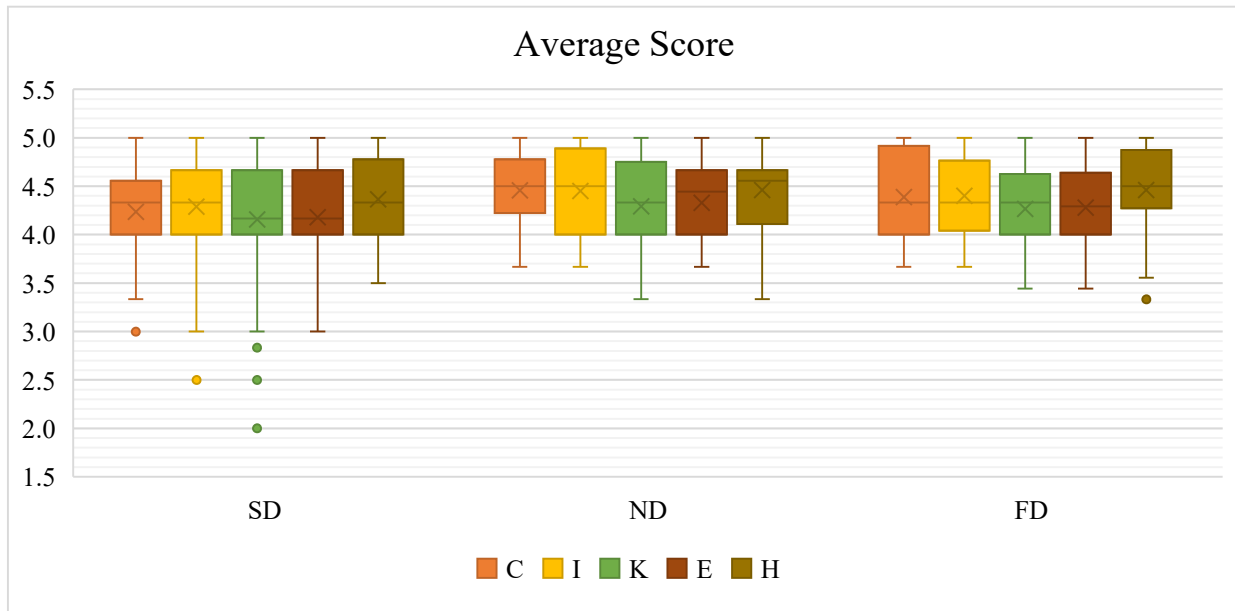

Figure 2: The average score of CIKEH for each diversity category.

4.3. Team Conflict

Another section we collected feedback on is team conflict. Students answered a total of nine questions related to three different conflict aspects: Task Conflict (**TC**), Process Conflict (**PC**), and Relationship Conflict (**RC**) and the questions are summarized in Table 2. All the questions are answered using a 5-point Likert scale, with 1 being the least amount of conflict, and 5 being the most amount of conflict. The average score for each aspect is calculated per student first, then per team, followed by averaging over the diversity categories, which is summarized in Fig. 3.

All the teams within the different diverse categories experienced lower conflict scores, without any significant differences among them. This result suggests that team diversification has negligible to no impact at all on conflict that may arise within a team.

Table 2: Questions used for assessing Team Conflict.

	Questions
Task Conflict (**TC**)	How much conflict of ideas is there in your work group?
	How frequently do you have disagreements within your work group about the task of the project you are working on?

|	How often do people in your work group have conflicting opinions about the project you are working on?
Process Conflict (*PC*)	How often do you disagree about resource allocation in your work group?
	How often are there disagreements about who should do what in your work group?
	How much conflict is there in your group about task responsibilities?
Relationship Conflict (*RC*)	How much relationship tension is there in your work group?
	How often do people get angry while working in your group?
	How much emotional conflict is there in your work group?
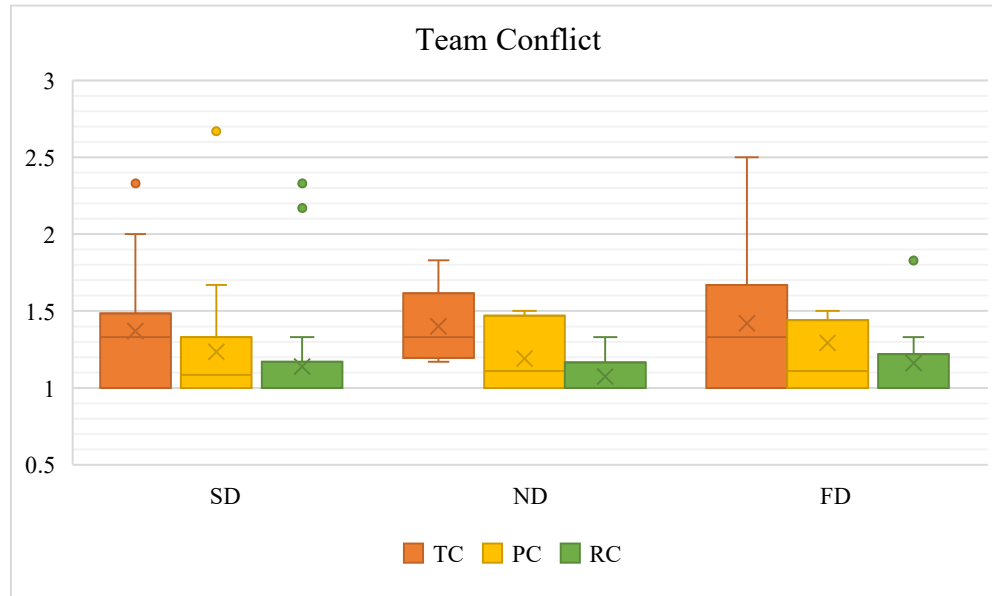
Figure 3: The average score of the three different aspects for Team Conflict for each diversity category.
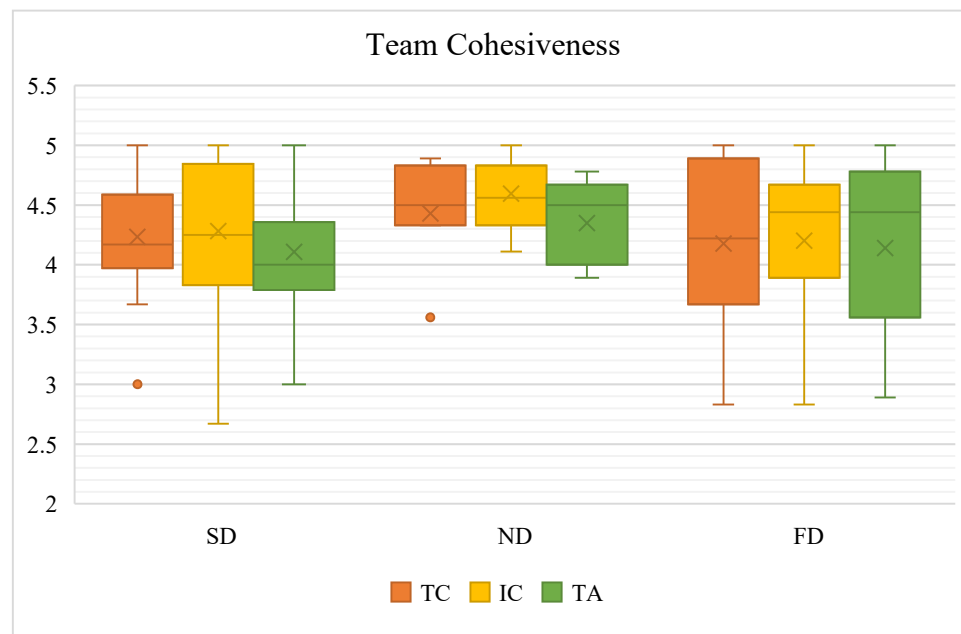
4.4. Team Cohesiveness

The fourth section the students were surveyed on was Team Cohesiveness. Students answered a total of nine questions related to three different cohesiveness aspects: Task Commitment (*TC*), Interpersonal Cohesiveness (*IC*), and Task Attraction (*TA*) and the questions are summarized in Table 3. All the questions are answered using a 5-point Likert scale, with 1 being the lowest and 5 being the highest score. However, two of the questions have a reverse scale, which is accounted for in the calculation of the average. The average score for each aspect versus the diversity categories is summarized in Fig. 4.

Although the average score for all the diversity categories is within the 4.1 ~ 4.6 range, the ND score was consistently higher than those of diverse teams (SD or FD). For the TC aspect, ND teams scored 4.7% more than diverse teams, whereas for the IC aspect, ND was higher by 9.5%. While the difference is not big, the authors think that this result, especially being consistent, does carry some insights within it. Perhaps ND teams have more things to share on a personal level (common background, societal aspects, shared heritage, …) that makes a non-diverse team more coherent than a diverse one.

Table 3: Questions used for assessing Team Cohesiveness.

	Questions
Task Commitment (**TC**)	Our team is united in trying to reach its goals for performance
	I'm unhappy with my team's level of commitment to the task [scale reversed]
	Our team members have conflicting aspirations for the team's performance [scale reversed]
Interpersonal Cohesiveness (**IC**)	Team members like each other
	Team members get along well
	Team members enjoy spending time together
Task Attraction (**TA**)	Being part of the team allows team members to do enjoyable work
	Team members get to participate in enjoyable activities
	Team members like the work that the group does

Figure 4: The average score of the three different aspects for Team Cohesiveness for each diversity category.

4.5. Team Psychological Safety

The last section surveyed the students about their psychological safety as part of their teams. Students answered a total of seven questions that are summarized in Table 4. Unlike the other sections of the survey, these questions are answered using a 7-point Likert scale, with 1 being the lowest and 7 being the highest score. Moreover, three of the questions have a reverse scale, which is accounted for in the calculation of the average. The average score of all the questions versus the diversity categories is summarized in Fig. 5. As depicted, the average score for all the diverse categories is the same, which, again, indicates that team diversification has a neutral effect on the psychological safety of the students.

Table 4: Questions used for assessing Team Psychological Safety

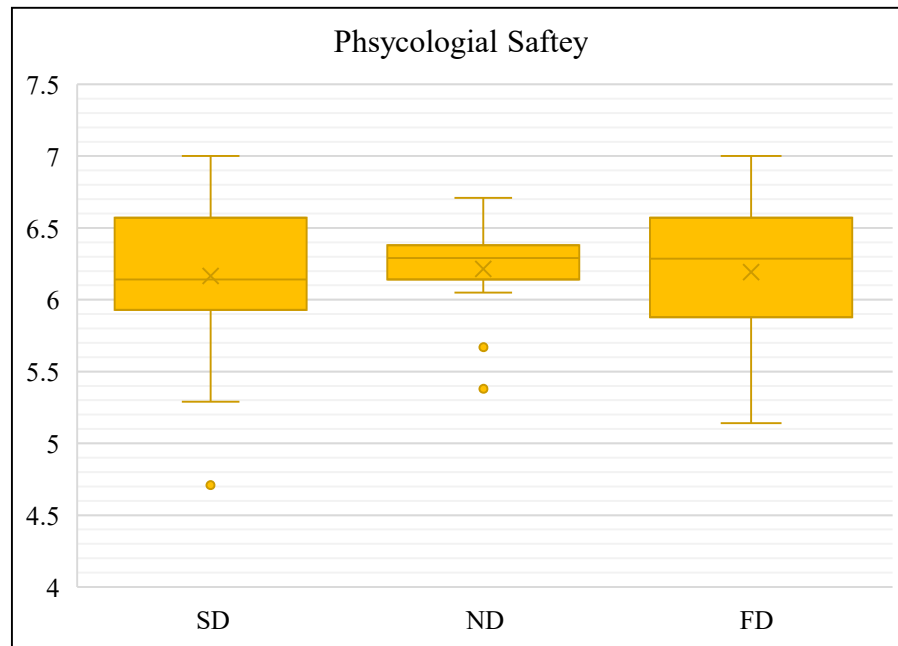| Questions |
| --- |
| If you make a mistake on this team, it is often held against you. [scale reversed] |
| Members of this team are able to bring up problems and tough issues. |
| People on this team sometimes reject others for being different. [scale reversed] |
| It is safe to take a risk on this team. |
| It is difficult to ask other members of this team for help. [scale reversed] |
| No one on this team would deliberately act in a way that undermines my efforts. |
| Working with members of this team, my unique skills and talents are valued and utilized. |

Figure 5: The average score of the nine Psychological Safety questions versus each diversity category.

5. Summary and Conclusions

In this WIP study, we explored the impact of team diversity on various aspects of team dynamics, including satisfaction, cohesiveness, conflict, and psychological safety, in an undergraduate engineering course. While the findings suggest that the diversity composition of a team does not significantly affect overall team dynamics, there were some noteworthy patterns. Teams categorized as ND tended to report slightly higher satisfaction and cohesiveness scores, particularly in areas of interpersonal cohesiveness and task commitment. However, team conflict remained largely unaffected by diversity levels. These results underscore the complexity of team dynamics and the need for further investigation into how diversity influences not only team performance but also interpersonal interactions. Future studies could delve deeper into the long-term effects of team diversity in engineering education and beyond.

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