The Role of Diverse Teams in Engineering Innovation: A Case Study of Graduate Programs at an HBCU.

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ABSTRACT

Engineering innovation is increasingly viewed as a product of collaborative, diverse teams that leverage a range of perspectives and experiences. This study primarily examines how diverse teams in graduate engineering programs at an HBCU contribute to innovation in problem-solving, creativity, and research outcomes. Specifically, it investigates the unique advantages that diverse teams offer over homogeneous teams (defined as teams with members from similar backgrounds in terms of race, gender, socioeconomic status, and academic experience) in fostering innovation, particularly within STEM fields. Grounded in Social Capital Theory, which posits that social networks and diverse relationships enable the flow of information and resources that drive innovation, this research focused on three key areas: diverse inputs, cognitive diversity, and innovative outputs.

Diversity was explored in terms of race, gender, socioeconomic background, and academic experience, while innovation outcomes were measured through metrics such as patents filed and research papers published. The research explores how diversity in team composition influences the problem-solving process, team performance in innovation tasks, and the role of institutional support in enhancing these outcomes. A mixed-methods approach was employed, combining quantitative analysis of innovation outcomes with qualitative interviews focusing on team dynamics and problem-solving strategies. For the quantitative analysis, Excel was used to calculate descriptive statistics, correlations, and mean scores to examine relationships between team diversity and innovation metrics. Specific tests, such as correlation analysis and t-tests, were used to assess the impact of diversity on performance outcomes.

The qualitative data from interviews were analyzed thematically to identify common patterns and insights related to team collaboration and creativity. By examining teams from multiple STEM research laboratories at an HBCU, this study highlights the critical role of such institutions in promoting diversity and fostering innovation in engineering education. The findings suggest that diverse teams, supported by institutional resources and a collaborative environment, lead to more creative problem-solving and higher innovation outcomes, providing valuable insights for both academic and industry settings to enhance team formation and innovation in STEM disciplines.

Keywords: Diverse Teams, Engineering Innovation, Historically Black Colleges and Universities (HBCUs), Graduate Engineering Programs, Collaborative Problem-Solving, Creative Collaboration, STEM Research.

1.0 INTRODUCTION

Innovations in engineering have long been recognized as a very crucial driver of technological advancement, economic growth, and societal advancement [1]. Although, the traditional approaches to innovation, which is often rooted in homogeneous teams (comprising individuals with similar demographic or experiential characteristics e.g., race, gender, and academic program background) are increasingly being challenged by the advantages of diversity [2]. For instance, diverse teams comprising individuals with different racial, gender, socioeconomic, and academic backgrounds have been proved to foster creativity and problem-solving in ways that homogeneous teams cannot [3], [4]. Research has highlighted that diversity contributes to a broader range of perspectives, which enhances the ability to identify novel solutions and improve decision-making processes [5], [6]. Despite this growing recognition of the value of diversity, there remains a gap in understanding how diverse teams specifically contribute to engineering innovation, particularly within the context of graduate programs at Historically Black Colleges and Universities (HBCUs) [7].

HBCUs, as institutions with rich cultural histories and strong commitments to diversity, present a unique environment for studying the impact of diverse teams in STEM education [8]. These universities have long played a pivotal role in providing access to higher education for historically marginalized groups and have produced significant contributions to science, technology, engineering, and mathematics (STEM) education [9]. However, research exploring the dynamics of diverse teams within HBCUs, particularly in engineering graduate programs, is limited [10], [11]. Understanding how diverse teams within these programs impact innovation in research, problem-solving, and creativity is crucial for both academic institutions and the broader engineering community, especially given the increasing demand for innovation to address complex global challenges [12], [13].

Although, the question of how diverse HBCUs are within the country is still of interest and why they are not currently represented in higher education literature and research on diversity [14]. The sociopolitical environment is one of the many elements that have affected Black students' enrollment in HBCUs. For example, a 17–22% rise in Black first-time student enrollment at HBCUs is predicted for every standard deviation increase in state-level hate crime reports [15]. Talking about gender gap, more Black women are enrolled in college than Black men, indicating a sharp increase in the gender enrollment gap between the two groups [16].

This study seeks to address this gap by investigating the role of diverse teams in graduate engineering programs at an HBCU, focusing on how diversity in race, gender, socioeconomic background, and different academic program background experience contributes to innovation outcomes in a team. The research aims to identify the mechanisms through which diversity in terms of the characteristics mentioned enhances team performance in problem-solving, and creative tasks and also to explore how institutional support can further facilitate these outcomes.

By employing a mixed-methods approach, which includes both quantitative analysis of innovation metrics and qualitative interviews with team members, this research provided valuable insights into the role of diverse teams in fostering engineering innovation, with the potential to inform best practices in both academia and the industry.

Research Questions

The following research questions guided this study:

i. How does diversity (race, gender, socioeconomic, and academic background) impact innovation in graduate engineering teams at HBCUs?

ii. How do team dynamics (e.g. communication, trust, collaboration) influence innovation in graduate engineering teams?

iii. What role does institutional support play in enhancing the innovation outcomes of graduate engineering teams?

iv. What strategies can academic institutions and industry use to optimize innovation through graduate engineering teams?

2.0 BACKGROUND AND LITERATURE REVIEW

The role of diversity in fostering innovation has gained reputable attention across various fields, particularly in STEM disciplines, where collaborations and problem-solving are very essential for addressing complex challenges. In engineering, the ability to bring together diverse perspectives is increasingly recognized as a critical factor in driving creativity, enhancing decision-making, and improving outcomes [5], [6]. Historically, engineering teams were often composed of individuals with similar backgrounds, yet this traditional model has been questioned as research suggests that diversity can lead to superior performance by encouraging creative friction, broader thinking, and more innovative solutions [17].

Diverse teams in engineering bring together individuals with different cognitive frameworks, experiences, and approaches to problem-solving, which can be particularly valuable in an academic setting. A key theory that underpins the value of diversity is Social Capital Theory, which argues that networks and diverse relationships facilitate the flow of information and resources necessary for innovation [18], [19]. By bridging gaps in knowledge and enhancing the exchange of ideas, diverse teams are better positioned to develop groundbreaking solutions [20]. This notion aligns with the findings of Mello and Delise [21]; and Garrison et al. [22], who suggested that diversity not only imparts creativity but also decision-making, trust, and group cohesion, which are essential components of innovative team dynamics.

According to the Social Identity Theory (SIT), people's conduct and interactions are influenced by the groups they belong to, which helps them identify who they are [23]. SIT emphasizes how students from various origins contribute distinctive viewpoints that might spur engineering innovation in the context of diverse teams at HBCUs. Because various experiences lead to distinct approaches to problem-solving, diversity among these teams can foster innovation [5]. This feeling of community can improve cooperation, foster support, and assist in overcoming obstacles at HBCUs, where a large number of students have similar cultural identities. This can result in more creative results and improved teamwork [24].

There are various types of team diversity ranging from race, ethnicity, cognitive and disciplinary diversity. Differences in how people think, process information, solve issues, and make decisions are referred to as cognitive diversity. It's about having different ways of thinking, different viewpoints, and different cognitive styles in a group. This type of diversity can result from variations in psychological attributes like receptivity to new experiences, creativity, problem-solving techniques, or even IQ. Because individuals with diverse thought processes are more inclined to approach challenges in novel ways, cognitive diversity is beneficial because it fosters more creative solutions [21], [25], [26].

On the other hand, disciplinary diversity emphasizes the range of skills and information that individuals contribute according to their professional or educational backgrounds. When it comes to problem-solving, individuals from various academic or professional fields (such as engineering, marketing, psychology, or law) bring unique tools, approaches, and viewpoints. This type of diversity enhances conversations and aids teams in resolving complicated issues by addressing them from several perspectives [27].

While the benefits of diversity are well-documented, the specific impact of diversity within the context of graduate engineering programs at Historically Black Colleges and Universities (HBCUs) still needs more attention [28]. HBCUs have a unique role in engineering education, providing opportunities to marginalized groups and fostering inclusive academic environments [29]. These institutions have long contributed to the development of underrepresented groups in engineering and science, but their influence on diverse teams' role in innovation is not fully understood. HBCUs have a rich history of producing talented engineers and researchers who often go on to make significant contributions in academia, industry, and government [30], [31], [32].

Research on diverse teams in STEM fields has predominantly focused on organizations and industry settings [33], [34], yet few studies have examined the impact of such teams within the academic context of graduate programs. In a review study by Joshi and Roh [33], the authors identified the positive effects of team diversity on performance outcomes, particularly when institutional structures supported these teams through appropriate resources and mentorship. Similarly, in examining diverse teams within academic settings, a study by Page [5] noted that

heterogeneous groups outperformed homogeneous ones in complex tasks, such as engineering design and research, which require creativity and adaptive problem-solving [35], [36]. The results in this research aligns with the opinions of the authors by showcasing the effectiveness of the diverse teams in engineering innovation.

At the same time, there is a growing recognition that diversity alone is not sufficient for fostering innovation. The environment within which diverse teams operate plays a crucial role in their success. Institutional support, access to resources, and the promotion of inclusive cultures are key factors that influence how diverse teams perform [5], [37]. For example, studies have shown that institutional efforts, such as mentorship programs and diversity-centered policies, can significantly enhance the innovation outcomes of diverse teams by ensuring that they have the resources and organizational backing needed to succeed [37], [38].

Thus, there is a compelling need to explore how diversity within graduate engineering programs, particularly in HBCUs, impacts innovation in problem-solving, research, and creativity. This study aims to fill this gap by focusing on the dynamic relationship between diverse team composition and innovation outcomes in engineering fields [39], [40]. By investigating teams from various engineering disciplines at an HBCU, this research seeks to provide insights into how diversity contributes to the effectiveness of collaborative problem-solving and innovation, with the goal of informing best practices for both academic and industrial settings [41].

3.0 THEORETICAL FRAMEWORK

This research is grounded in two theories, Social Capital Theory (SCT) is of the idea that social relationships and networks can be good resources that help people develop and accumulate human capital [42], [43]. That is the ability to get resources and information needed for better performances. In the context of HBCU graduate programs, SCT argues that the different social networks created by diverse teams can improve access to special insights and expertise, creating an atmosphere that encourages engineering innovations.

The integration of diverse backgrounds and experiences within teams at HBCUs may strengthen social networks, where cooperation and support among team members can spur greater levels of creativity and problem-solving that are necessary for engineering innovations.

The second theory employed is the theory that Henri Tajfel and John Turner created, the Social Identity Theory (SIT), which describes how people organize themselves and other people into social groups according to traits including race, ethnicity, gender, and profession. According to SIT, people establish an in-group (a group they identify with) and see others as belonging to an out-group. SIT holds that people get some of their identity from the groups they are a part of [44], [45]. Group dynamics, attitudes, and conduct are all impacted by this classification process.

These divisions may have an impact on how members of a team communicate, work together, and value one another's contributions. Students' relationships in engineering teams are influenced by their social identities, which are affected by their ethnicity, cultural background, and academic field in the context of graduate programs at Historically Black Colleges and Universities

(HBCUs). Group cohesiveness, dispute resolution, and eventually creative processes are all significantly influenced by these identity-driven dynamics. The way people relate to one another based on their shared or different identities can either help or hinder the development of innovative ideas and creative solutions in diverse engineering teams.

Engineering students at HBCUs frequently traverse a special environment where they interact with engineering teams that unite people from diverse social backgrounds while simultaneously potentially belonging to an in-group characterized by similar racial or cultural experiences. A helpful lens for comprehending how these various identities interact and affect teamwork is provided by social identity theory. Students from minority backgrounds in STEM, for example, could feel more united within their in-group while also finding it difficult to communicate with members of the out-group, which can impact team dynamics and innovation [46]. However, this conflict can also create a setting where different viewpoints might lead to creative solutions for challenging engineering issues.

SIT helps identify the underlying psychological and sociological factors that influence the success (or failure) of diverse teams by looking at how social identities influence team formation, communication, and conflict resolution in engineering projects. Particularly in institutions like HBCUs, where student diversity is both a strength and a possible obstacle, an inclusive atmosphere that fosters collaboration and technical innovation requires an understanding of these interactions.

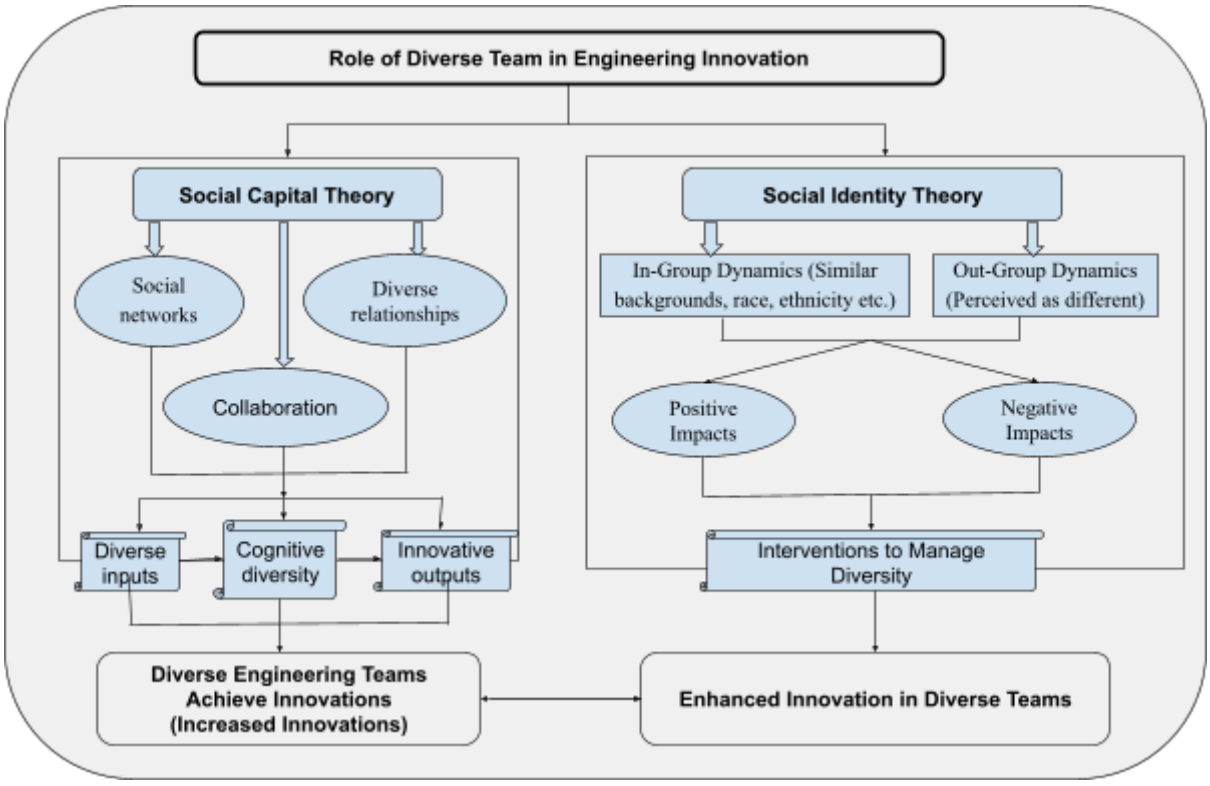

Figure 1. Conceptual Framework for the Role of Diverse Teams in Engineering Innovation (Adapted from SCT & SIT, Henri Tajfel and John Turner (1979)

4.0 METHODOLOGY

The impact of diversity on innovation in engineering graduate student teams is examined in this study, with particular attention paid to the ways in which team dynamics are impacted by differences in demographics and academic backgrounds. The study looks into how academic specialization, gender, and ethnicity impact teamwork, creativity, and communication when addressing problems. In order to identify strategies that can improve team performance in varied settings, this study looks at both the advantages and possibly difficult consequences of diversity. In order to give a thorough analysis of team interactions, performance, and innovation processes, a mixed-methods approach was used, combining quantitative surveys and qualitative interviews [47].

Participants

The study involved forty (40) engineering graduate students (37 international, and 3 domestic) across various programs such as Sustainable Infrastructure Engineering, Civil Engineering, Industrial Engineering, Electrical and Computer Engineering, and Transportation Engineering. Using multiple characteristics of three or more (from race, gender, academic background, and socioeconomic background) the participants were grouped into both homogeneous and diverse teams. A team with a single or maximum of two characteristics is grouped as “homogeneous”, while a team with multiple i.e. three or more characteristics is termed “diverse”, with a focus on teams engaged in research projects within their respective disciplines. A purposeful sampling strategy was used to select participants with relevant experience and knowledge [48], [49]. In the content and focus of this research, a team with a single characteristic from race, gender, socioeconomic, or academic backgrounds is grouped as an homogeneous team. While a team with a multi characteristic is grouped as a diverse team (IRB approval was obtained IRB #19/04-0062).

For the purpose of this research seven (7) major diverse teams were identified with research focus spanning Sustainable and Resilient Innovation, Landslide and Slope Stability, Climate Resilient, Urban Flooding, Experiment-Centric Pedagogy (ECP) in STEM, Soil Erosion, and Low Carbon Concrete Research respectively. Thirty three (33) respondents participated from this team. Seven (7) members from two (2) Homogeneous teams with research focus in Smart Transportation and Transportation Research respectively also participated.

Data Collection methods

Data was collected using two primary methods: Quantitative and Qualitative
Quantitative data (Questionnaire): A structured questionnaire was administered to both teams, adapting validated instruments such as the Global Diversity and Inclusion Benchmarks (GDIB), the Team Innovation Implementation (TII) [50], [51], [52], and the Social Capital instruments [53]. These tools were targeted at assessing various aspects of team diversity, communication,

trust, collaboration, and innovation. The responses were collected using a 5-point likert scale, ranging from 1 to 5 (i.e. Strongly Disagree to Strongly Agree) [54]. See table 1

Table 1. Sample questions from the questionnaire.

S/No	Question	Strongly Agree (SA)	Agree (A)	Neutral (N)	Strongly Disagree (SD)	Disagree (D)
A	Demographic Diversity					
1.	Our team has a diverse composition in terms of race and ethnicity					
2.	There is gender diversity in our team					
3.	Having diverse backgrounds in terms of academic experience (e.g., different undergraduate disciplines) is valuable for our team					
B	Team Communication and Cohesion					
4.	Our team communicates effectively when working on tasks					
5.	Our team feels cohesive and works well together despite our differences					

Qualitative Data Gathering

The qualitative data source for this study includes semi structured interview sessions. The semi structured interview was designed to elicit the students' experiences on the impact of diversity on innovation in engineering graduate student teams. The students were asked questions about their experiences in the diverse team dynamics that influence innovation in the engineering program they were in? The students were further asked to describe a situation where social relationships within their team led to a breakthrough or a new idea? They were also asked to describe the networks and resources at their HBCU that contributed to their team's problem-solving capabilities. The semi-structured interviews were conducted with selected participants (including 13 students and 2 faculty members), 9 participants from the diverse teams and 4 from the homogeneous teams. For a balanced representation of opinion, and to gather in-depth insights into their experiences with team dynamics, the value of diversity, institutional support, and its impact on innovation. The interview questions were structured to explore perceptions around team cohesion, creativity, and problem-solving, as used by Hu and Chang [55] for capturing rich qualitative data. The interview responses were transcribed and arranged in excel alongside the responses from the open ended questions of the questionnaire.

5.0 DATA ANALYSES AND RESULTS

Qualitative Data Analysis

Serendipitous Discovery Through Networking: While combing through the data, this theme stood out as participants mentioned how networking with other diverse participants led to discovery of problem solving ideas. Excerpts of this theme are *"people from different cultures and disciplines help expand our thinking beyond what we already know."* Another excerpt is a participant saying *"the mix of experiences and viewpoints enhances the depth of problem-solving."* Another participant noted that innovative discovery resulted from the diverse team saying, "team diversity brings in alternative viewpoints that help overcome engineering roadblocks."

Cross-Pollination of Ideas: A second major theme from the data of this study saw participants describing how the diversity in a team led to cross-pollination of ideas. One participant described this saying *"our diverse backgrounds allowed us to cross-pollinate ideas and come up with an innovative solution."* Another participant mentioned that *"with people from varied backgrounds, we can create more innovative solutions by merging different skill sets."* A participant also described this theme saying *"diverse teams bring different perspectives that challenge conventional thinking."* Other participants further explained this theme saying diversity of the team gave more robust results than an homogenous group result would have produced stating that diverse teams "bring different viewpoints and problem-solving strategies, which helps us to approach engineering tasks and challenges from multi-lens and angles."

Utilizing Diverse Networks: The qualitative data from this study showed that the participants experienced noticeable improvement on their projects result due to utilizing the diversity of the members on the project. A participant described this noticeable improvement saying that *"diverse teams are better at finding creative solutions because of the variety of approaches to the same problem."* Another participant noted that *"when diverse minds come together, it often leads to breakthrough ideas that wouldn't happen in homogenous teams."* This theme drove the point of having a diverse team, pointing out that when brainstorming for a solution, "diversity sparks creativity by providing different angles from which to tackle challenges."

Knowledge Sharing Beyond Formal Meetings: The fourth major theme that was generated from the data of this study is 'Knowledge Sharing Beyond Formal Meetings'. In this theme, participants described how hanging out with other team members socially led to innovative ideas. An excerpt of this theme is seen in a participant saying that *"socializing and brainstorming together outside meetings led us to refine our research questions."* Another participant mentioned that *"during informal chats, one team member shared a unique idea that inspired a significant shift in our project approach."* Also, a participant pointed out that *"during a casual discussion with a professor, we received feedback that helped us refine our project and move in a more innovative direction."*

Leveraging Community for Resource Sharing: The last major theme obtained from the qualitative data for this study described how resources from their HBCU and partnering institutions provided resources for the team project. A participant noted this saying that *"our HBCUs collaborations with other universities have helped us access unique resources for our projects."* Another participant pointed out that *"the university's technology and software resources have been invaluable for developing our engineering solutions."* Also, a participant said that their *"HBCU provides a solid network of alumni who offer advice and insight that enhance our work."*

The role of institutional support also emerged as a critical factor in team innovation. The question is *"Access to Resources and Institutional Support [Our institution provides sufficient resources (e.g., funding, equipment) to support team innovation"* Participants highlighted the significance of having access to sufficient resources, including funding, equipment, and mentorship, in enabling diverse teams to achieve high-quality research outcomes. A participant said *"We enjoyed support from the school, especially mentorship through the faculty members"*. Teams with strong institutional backing reported better innovation outcomes, which was also reflected in the quantitative data.

These results from the data analysis provided valuable insights into the role of diverse teams in fostering innovation within engineering graduate programs. The analysis of the qualitative data reveals several key findings that underscore the positive impact of diversity on team dynamics and innovation outcomes.

Quantitative Data Analysis

The responses from the structured questionnaire were entered into Excel 2016, where descriptive statistics and PivotTables were first used to summarize the data. Frequency distributions and averages were calculated for each question to determine the most common responses and assess overall trends. This approach provided insight into the participants' views on various aspects of team diversity, communication, collaboration, and innovation.

To assess the impact of demographic diversity on team performance, we focused on several key variables: demographic diversity (race, gender, socioeconomic background, and academic experience), team communication and cohesion, trust and collaboration, creativity and problem-solving, access to resources and institutional support, and networking and information sharing.

A comparative analysis was conducted using Excel's t-test functionality to examine whether there were significant differences in responses between these two groups. Additionally, correlation analysis was performed to explore the relationships between different variables. Because of the nature of the data collected and the research methodology, other statistical tests including regression analysis and chi-square were not given priority in this study. Since the

analysis focused on comparing means (i.e., utilizing continuous data) between the Diverse and Homogeneous Teams, the T-test was more appropriate than the chi-square test, which is usually used for categorical data (e.g., Yes/No) to explore correlations between variables.

Moreso, this study did not focus on regression analysis, which is typically used to forecast correlations between variables or evaluate the direction and strength of causal links. A T-test and correlation analysis were adequate for comparing means and examining the degree of relationships between variables within the framework of the study objectives, considering the small sample size of 40 participants.

Quantitative Data Results

In the context of graduate engineering programs at an HBCU, the results in table 2 clearly show a difference between diverse and homogeneous team responses, especially with regard to communication, cohesiveness, and innovation. When it comes to open idea exchange, good communication, and the capacity to develop original solutions to technical problems, diverse teams routinely report high levels of agreement. Conversely, homogeneous teams have significantly lower levels of agreement on communication and problem-solving, and they frequently disagree or stay neutral on comparable metrics. These results imply that racial, gender, and socioeconomic diversity are important factors in promoting productive team dynamics and stimulating technical creativity. The varied teams' impressive results in these domains highlight how crucial inclusion is for improving teamwork, creativity, and idea production.

Table 2. A preview and extracts of responses from the questionnaire, homogeneous team in black color and diverse team in red color.

Question / Team Type	Demographic Diversity (Race, Gender, Socioeconomic Background) [The team includes individuals from various socioeconomic backgrounds.]	Team Communication and Cohesion [Our team communicates effectively when working on tasks.]	Team Communication and Cohesion [Team members openly share their ideas and knowledge.]	Creativity and Problem-Solving [Our team often comes up with novel solutions to engineering challenges.]
Diverse	Agree	Agree	Agree	Agree
Diverse	Strongly agree	Strongly agree	Neutral	Agree
Diverse	Strongly agree	Strongly agree	Strongly agree	Strongly agree
Diverse	Strongly agree	Strongly agree	Strongly agree	Strongly agree
Diverse	Strongly agree	Strongly agree	Strongly agree	Strongly agree
Homogeneous	Strongly disagree	Strongly disagree	Strongly disagree	Neutral
Homogeneous	Strongly disagree	Strongly disagree	Disagree	Neutral
Homogeneous	Strongly disagree	Strongly disagree	Neutral	Disagree
Homogeneous	Disagree	Disagree	Neutral	Neutral
Homogeneous	Disagree	Disagree	Disagree	Neutral

Team Composition and Diversity

Results in table 3 shows the demography that diverse team has better composition in terms of race and ethnicity, comprises of individuals from various socioeconomic backgrounds, including gender diversity, and different academic backgrounds, based on the level of strong agreement to the questions, while the homogeneous team members mostly, and strongly disagree or disagree that their team actually fulfil the characteristics of race, gender, academic and socioeconomic backgrounds.

Table 3. Demographic Diversity in Diverse and Homogeneous Engineering Teams

Diverse Team (DT) = 33 Homogeneous Team (HT) = 7	**DT**	**HT**	**DT**	**HT**	**DT**	**HT**	**DT**	**HT**	**DT**	**HT**
Diversity Aspect	**SA**		**A**		**SD**		**D**		**N**	
Our team has a diverse composition in terms of race and ethnicity	15	0	15	0	0	3	0	4	3	0
Team includes individuals from various socioeconomic backgrounds	15	0	15	1	1	4	0	1	3	1
Gender diversity present in the team	14	0	14	0	2	5	3	2	0	0
Diverse academic backgrounds (e.g. undergraduate disciplines)	17	1	14	0	2	4	0	1	0	1

Note: Diverse Team (DT), Homogeneous Team (HT), Strongly Agree (SA), Agree (A), Strongly Disagree (SD), Disagree (D), Neutral (N)

Communication and Cohesion

With 80% of respondents in table 4 agreeing or strongly agreeing that their team communicates successfully during tasks, the table demonstrates that diverse teams report great communication and cohesion. 22.5% disagree, whereas 70% feel comfortable constructively questioning one another's opinions. Furthermore, 77.5% of people feel united and collaborate effectively in spite of differences. Homogeneous teams, on the other hand, disagreed or stayed neutral on these points, suggesting that less diversified organizations had difficulties with cohesiveness, communication, and idea sharing. This demonstrates the potential advantages of diversity in promoting improved problem-solving and teamwork.

Table 4. Team Communication and Cohesion

Question	Strongly Agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly Disagree (%)
Our team communicates effectively when working on tasks	37.5	42.5	2.5	5	12.5
Team members are comfortable challenging each other's ideas in a constructive way	32.5	37.5	7.5	0	22.5
Our team feels cohesive and works well together despite our differences	32.5	45	7.5	0	15

Trust and Collaboration

According to table 5 and fig. 3, diverse teams report higher levels of cooperation, respect, and trust than homogeneous teams. The homogeneous teams mostly disagreed or stayed neutral on this issue, but 75% of participants in diverse teams agreed or strongly agreed that they trust their teammates to contribute in a meaningful way. Similarly, homogeneous teams exhibit less agreement, with some disagreement, whereas 87.5% of varied team members concur that there is mutual respect. When it comes to cooperation, 77.5% of varied team members are open to working together on novel concepts, but homogeneous teams are less open, with many members disagreeing or staying neutral. This suggests that in order to promote openness, respect, and trust in teams, diversity is essential.

Table 5. Trust and Collaboration Results

Question	Strongly Agree (%)	Agree (%)	Strongly Disagree (%)	Disagree (%)	Neutral
I trust my team members to contribute meaningfully	35	40	2.5	5	17.5
There is mutual respect among team members	40	47.5	2.5	5	5
Our team is willing to collaborate on unconventional ideas	42.5	35	5	2.5	15

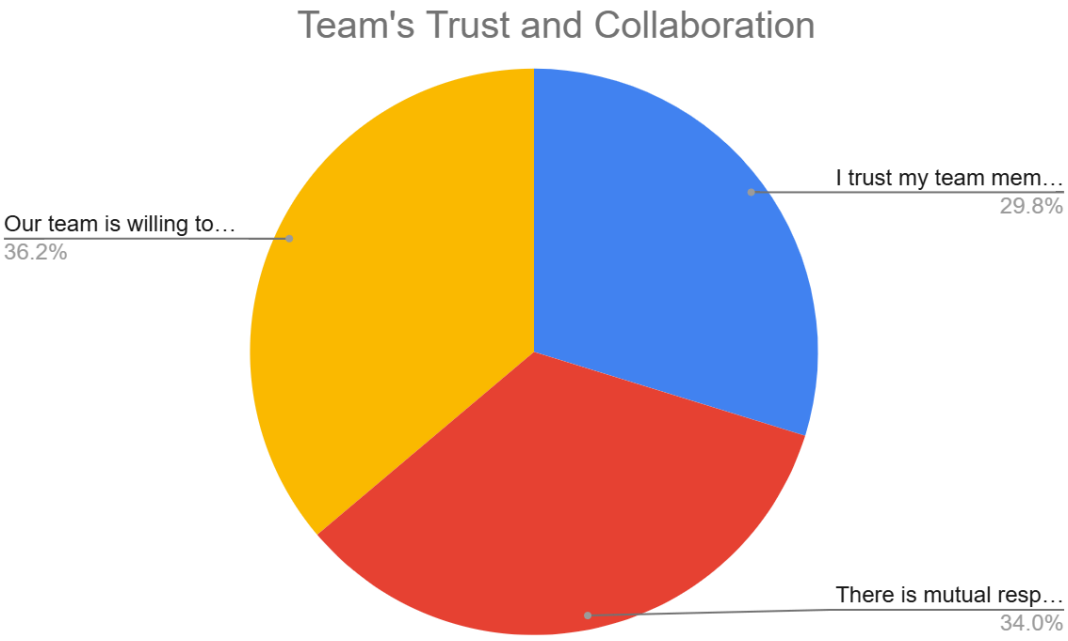

Figure 3. Team Perception on Trust and Collaboration

In table 6, as compared to homogenous teams, diverse teams typically report better results in terms of originality and research success. While homogenous teams exhibit greater disagreement or stay neutral, the majority of diverse teams agreed, with 35% strongly agreeing that their diversity has resulted in more creative problem-solving. Similarly, homogeneous teams exhibit more neutrality or disagreement, whereas diverse teams indicate favorable influences on their research (70% agree or strongly agree). Nevertheless, despite the general tendency, almost two homogeneous team members concurred that their group has produced high-quality research, indicating a minor positive effect in this area.

Table 6. Creativity and Problem-Solving Results

Question	Strongly Agree (%)	Agree (%)	Strongly Disagree (%)	Disagree (%)	Neutral (%)
Our team often comes up with novel solutions to challenges	32.5	40	2.5	2.5	22.5
The diversity of our team has led to more creative problem-solving	35	32.5	2.5	2.5	27.5
Our team's diversity has positively influenced our research	35	35	5	7.5	17.5
Our team has been successful in producing high-quality research outputs	45	37.5	5	0	12.5

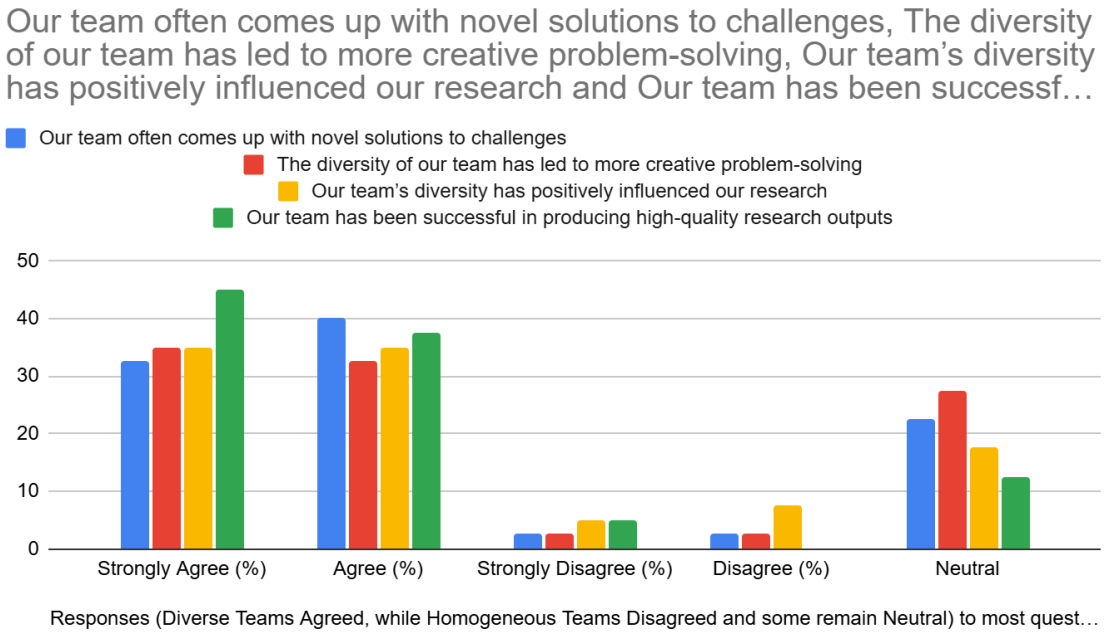

Figure 4. Team Perception on Creativity and Problem-Solving Impact

Access to Resources and Institutional Support

Table 7 shows that most diverse teams feel well-supported by the institution, with 57.5% agreeing or strongly agreeing that sufficient resources are provided. Similarly, 77.5% agree or strongly agree that mentorship is available to improve research. Regarding diversity support, 72.5% of diverse teams believe the institution actively supports diversity in its graduate engineering programs. In contrast, although some members from homogeneous teams also agreed, the majority disagreed or remained neutral, particularly concerning the availability of resources and diversity support, highlighting a disparity in the experience of support between diverse and homogeneous teams.

Table 7. Institutional Support and Resources

Question	Strongly Agree (%)	Agree (%)	Strongly Disagree (%)	Disagree (%)	Neutral
Our institution provides sufficient resources (e.g., funding, equipment)	15	42.5	2.5	0	40
We have access to mentorship that helps us improve our research	40	37.5	0	2.5	20
Our institution actively supports diversity in its graduate engineering programs	27.5	45	2.5	0	25

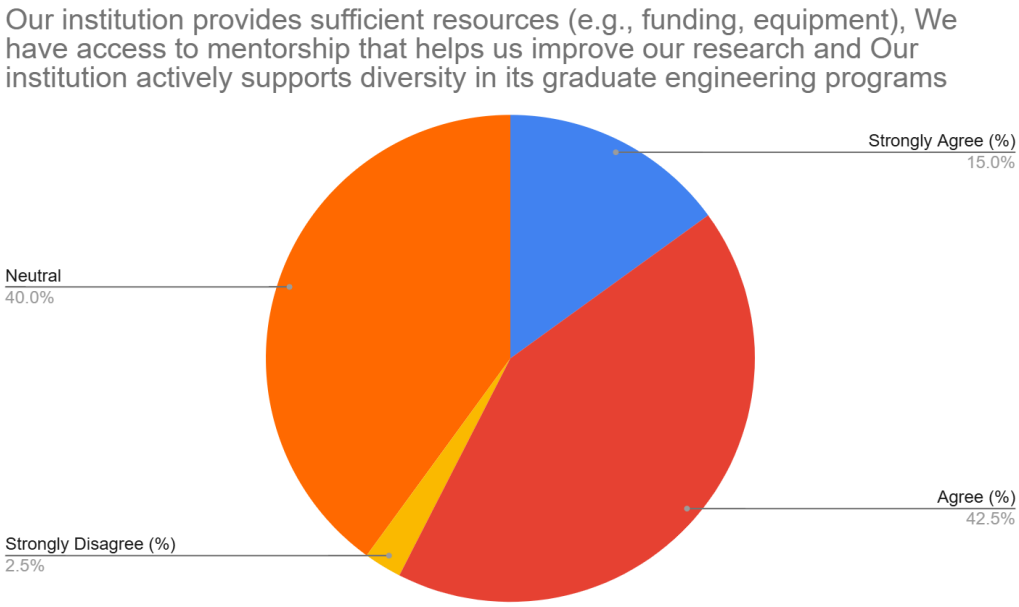

Figure 5. Respondents who agreed or strongly agreed with the statements about institutional support.

Networking and Information Sharing

Table 8 indicates that diverse teams benefit from a broader range of networks, with 75% agreeing or strongly agreeing that their diverse backgrounds help facilitate access to wider networks. Similarly, 77.5% of diverse teams believe collaborating with diverse members helps tap into different professional networks. In contrast, only 2 out of 7 homogeneous team members agreed with these statements, while the majority disagreed or remained neutral, suggesting that homogeneous teams may face limitations in accessing diverse professional connections and networks.

Table 8. Networking and Information Sharing Results

Question	Strongly Agree (%)	Agree (%)	Strongly Disagree (%)	Disagree (%)	Neutral
The diverse backgrounds of team members help facilitate access to wider networks	25	50	5	5	15
Collaborating with diverse team members helps us tap into different professional networks	30	47.5	0	5	17.5

Table 9. A general perspective of the diverse and homogeneous team on diversity questions

What is the research focus of your team?	Likert Scale					
Team Perception on Diversity Questions	**Agree**	**Disagree**	**Neutral**	**Strongly agree**	**Strongly disagree**	**Grand Total**
Diverse Teams	**16**		**3**	**14**		**33**
Agree	16					16
Neutral			3			3
Strongly agree				14		14
Homogeneous Teams		**4**			**3**	**7**
Agree		1				1
Disagree		1				1
Neutral		1				1
Strongly disagree		1			3	4
Grand Total	**16**	**4**	**3**	**14**	**3**	**40**

Descriptive Statistics Results

Means and Standard Deviations

The questionnaire's main themes which include demographic diversity, team communication and cohesiveness, trust and collaboration, creativity and problem-solving, institutional support, and networking and information sharing are shown in table 10 along with their respective averages and standard deviations. The means reflect overall agreement, while the standard deviations highlight response variability. Themes like Trust and Collaboration (4.04) and Team Communication and Cohesion (4.12) demonstrate significant agreement, although Institutional Support (3.88) and Demographic Diversity (3.85) point to potential areas that may need to be improved on. This analysis is essential for determining the graduate engineering programs' strong and weak points and for directing initiatives to improve institutional procedures and the student experience.

Table 10. Descriptive statistics for key variables

Variables from the Questionnaire	Mean	Standard Deviation
Demographic Diversity (Race, Gender, etc.)	3.85	0.72
Team Communication and Cohesion	4.12	0.63
Trust and Collaboration	4.04	0.58
Creativity and Problem-Solving	4.05	0.60
Institutional Support	3.88	0.73
Networking and Information Sharing	4.02	0.67

Correlation Coefficient (r)

Significant connections between different team dynamics and innovation outcomes are shown by the Pearson correlation analysis in table 11. As an illustration of how good communication fosters creativity, Communication and Cohesion exhibits substantial positive connections with Creativity and Problem-Solving (0.82) and Trust and Collaboration (0.72). Furthermore, there is a substantial correlation between Demographic Diversity and Networking and Information Sharing (0.65) and Creativity and Problem-Solving (0.75), indicating that diverse teams are more likely to access wider networks and produce innovative solutions. These results are important because they shed light on the ways in which various elements affect creativity, which may be used to develop tactics that improve team dynamics and create a more creative and cooperative atmosphere in graduate engineering programs.

Table 11. Correlations between key variables

Variable	Demographic Diversity	Communication and Cohesion	Trust and Collaboration	Creativity and Problem-Solving	Institutional Support	Networking and Information Sharing
Demographic Diversity	1.00	0.68[b]	0.56[a]	0.75[b]	0.49[a]	0.65[b]
Communication and Cohesion	0.68[b]	1.00	0.72[b]	0.82[b]	0.60[b]	0.70[b]
Trust and Collaboration	0.56[a]	0.72[b]	1.00	0.76[b]	0.57[a]	0.65[b]
Creativity and Problem-Solving	0.75[b]	0.82[b]	0.76[b]	1.00	0.69[b]	0.78[b]
Institutional Support	0.49[a]	0.60[b]	0.57[a]	0.69[b]	1.00	0.59[b]
Networking and Information Sharing	0.65[b]	0.70[b]	0.65[b]	0.78[b]	0.59[b]	1.00

Regression Analysis

In order to evaluate the combined effects of team diversity, communication, trust, and institutional support on creativity and problem-solving, the multiple regression analysis in table 12 was conducted. To determine each factor's relative impact on innovation results while adjusting for other variables, this analysis was required. The findings indicate that, with p-values of 0.001 and 0.004, respectively, Communication and Cohesion (0.35) and Demographic Diversity (0.25) significantly enhance creativity. With p-values of 0.050 and 0.008, trust and collaboration (0.18) and institutional support (0.22) also have a favorable impact on creativity. These results provide practical insights for enhancing team dynamics and institutional initiatives in graduate engineering programs by highlighting the value of diverse, cohesive, and supportive teams in promoting innovative problem-solving. Regression analysis is essential for determining the influence of each variable separately and comprehending how they interact to affect innovation.

Table 12. Multiple Regression Analysis Result

Intercept X Variable	Coefficient (C)	Standard Error	t-Statistic	p-Value
Demographic Diversity	0.25	0.08	3.13	0.004[b]
Communication and Cohesion	0.35	0.07	4.85	0.001[b]
Trust and Collaboration	0.18	0.09	2.00	0.050[a]
Institutional Support	0.22	0.08	2.75	0.008[b]

Distribution of Responses for Team Communication and Cohesion

The responses to the question "Team Communication and Cohesion [Team members are comfortable challenging each other's ideas in a constructive way.]" fig. 6 and 7 highlight the significant distinctions between the homogeneous and diverse teams. The bulk of responses for the diverse team fall into the "Agree" (44.1%) and "Strongly Agree" (38.2%) categories, indicating that team members are at ease having productive discussions and exchanging ideas. This suggests that the diverse team has a favorable opinion of communication and cohesion. With 42.9% strongly disagreeing and 57.1% remaining neutral, the homogeneous team, on the other hand, exhibits a clear pattern that suggests a lack of agreement or comfort in constructively questioning ideas. This discrepancy highlights possible difficulties in encouraging candid communication in uniform teams.

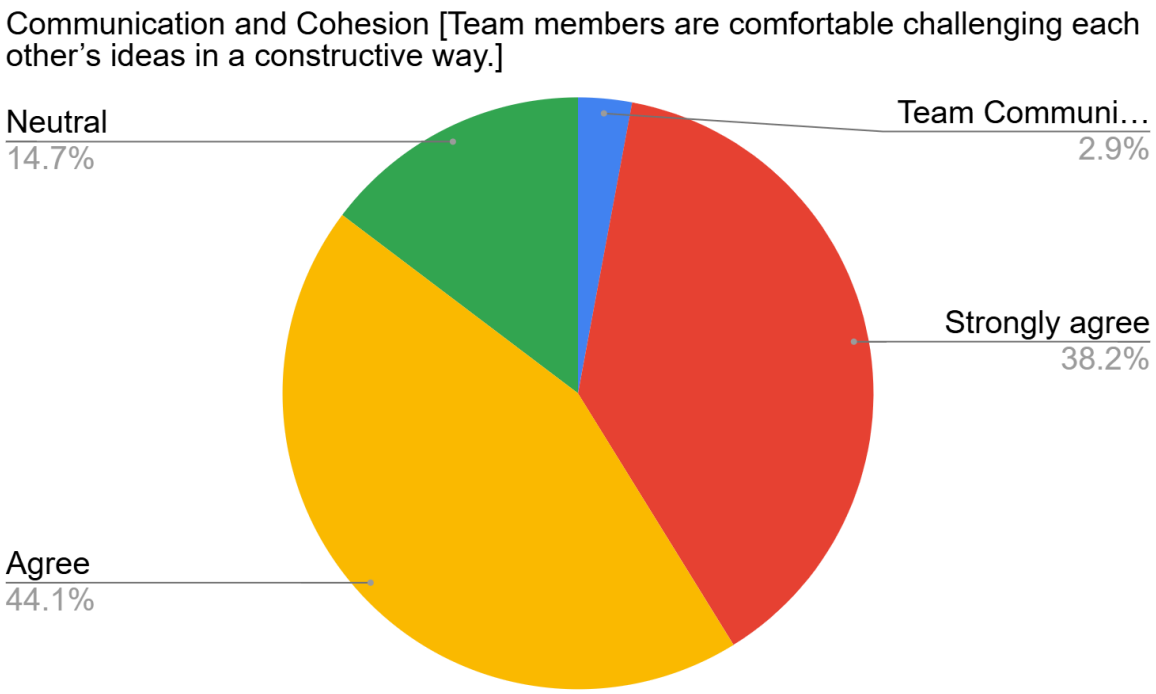

Figure 6. Team communication and cohesion responses (Diverse Team)

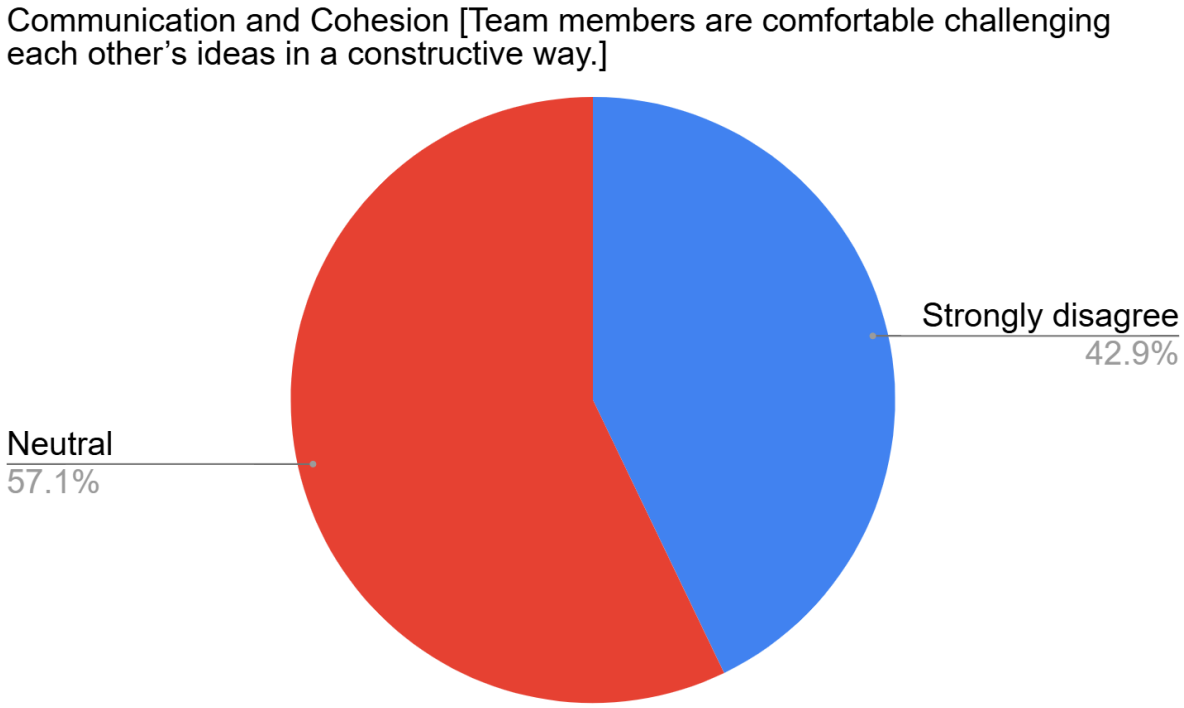

Figure 7. Team communication and cohesion responses (Homogeneous Team)

Team Diversity (race, gender, socioeconomic background) positively impacts team communication, trust, and creativity. Diverse teams tend to communicate better, collaborate more effectively, and exhibit higher levels of creativity and problem-solving skills. Strong Institutional Support and Networking capabilities also enhance creativity and collaboration, highlighting the importance of resources, mentorship, and institutional backing in fostering innovative teams. Team Communication and Cohesion is identified as a critical factor driving innovation, with a strong positive correlation with creativity and problem-solving.

Quantitative and Qualitative Data Integration

The integration of quantitative and qualitative findings revealed a strong alignment between the two data sets. The quantitative analysis showed that diversity positively correlated with creativity and problem-solving, while the qualitative interviews provided rich context for understanding why these correlations existed. Participants explained that it was not only the diversity of backgrounds but also the effective communication, collaboration, and institutional support that were also among the paramount factors that contributed to their success in solving complex engineering problems and producing innovative research.

The analysis revealed several important findings about the role of diversity in fostering innovation in engineering teams. First, diverse teams consistently reported better communication, higher creativity, and more successful problem-solving outcomes compared to homogeneous teams. This aligns with the quantitative results, which showed higher mean scores for diverse teams in these areas.

Additionally, teams that reported higher levels of trust, respect, and institutional support were more likely to produce innovative outputs such as research papers and patents. The combination of diverse backgrounds and institutional resources seemed to create an environment where creative ideas could thrive, leading to more groundbreaking solutions in engineering research.

5.0 DISCUSSION AND CONCLUSION

This research has explored how diversity in team composition influences the problem-solving process, team performance in innovation tasks, and the role of institutional support in enhancing these outcomes within engineering graduate student teams. The findings highlight the significant role of diversity (encompassing race, gender, and socioeconomic background) on key team dynamics such as communication, collaboration, and creativity, and are aligned with [5], [6], [17] and response to research questions one and two..

The results demonstrate that teams with diverse backgrounds exhibit stronger communication and cohesion, which in turn positively impacts problem-solving abilities and innovation performance, this actually answers research question two. Teams that value and leverage their diversity are more likely to generate creative solutions to complex engineering challenges.

Furthermore, institutional support i.e on the third research question (through resources, mentorship, and a commitment to diversity) has been shown to significantly bolster these outcomes, providing an environment where innovation can thrive [20], [21], [22].

The study also underscores the importance of fostering diversity in academic and professional teams, as it does not only enrich the team's intellectual resources but also promotes more effective collaboration and creative problem-solving. In addition, institutional support plays a crucial role in facilitating an environment that nurtures innovation by offering the necessary resources, support, and mentorship that diverse teams need to succeed, which answers the third research question [5], [33], [35], [36].

In conclusion, the research confirms that diversity, coupled with strong institutional backing, is a key driver of innovation in graduate engineering teams [37]. These findings can guide both academic institutions and industry stakeholders in structuring diverse teams and providing the necessary support and strategies (response to the fourth research question) to enhance problem-solving and innovation outcomes. Future research could explore further dimensions of diversity, including cognitive and disciplinary diversity, to build on these insights and refine strategies for fostering high-performing, innovative teams. This study was limited by the specific academic program (engineering) of the participating students. The findings may not be fully applicable to other disciplines. Future research with larger, and more diverse samples could enhance the generalizability of the results [57].

LIMITATIONS

While the study focuses on a single HBCU, and engineering innovation in graduate engineering programs, future research could expand to multiple institutions, programs as well as capturing more sample size for effects of diversity in team composition and respective outcomes.

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