Teamwork Perception in Engineering Programs through the Lens of Gender and Race

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Abstract

Teamwork skills are increasingly gaining importance in graduates' qualifications in engineering programs. The interconnected systems of the workflow of engineering products and projects necessitate certain technical and managerial skill sets. The need for multifaceted professionals is highlighted further by the advancement of tools and methods for remote collaboration on projects. This study's objective was to explore students' perceptions of the different aspects of teamwork. The first phase of this study was conducted in Fall 2022, in which students in the Construction, Biomedical, and Mechanical Engineering Departments at Mississippi State University were recruited to participate in a survey on different aspects of teamwork. A quantitative approach was used to ascertain essential facets of teamwork and provide content for in-depth exploration.

This paper contains two main result sections. The first one addresses similarities and differences between gender-based students' perceptions. The second section focuses on the perceptions of students from underrepresented groups and highlights distinctions among groups' responses. This study contributes to the body of knowledge by providing key aspects of teamwork that can be incorporated into engineering course layouts. Also, it reports on barriers and shortcomings in team-based practices and activities. The findings of this paper help engineering scholars and educators to design and develop opportunities to inclusively develop teamwork skill sets in engineering students.

Keywords: Engineering, Teamwork, Diversity, Gender, Education

INTRODUCTION

The ability to form teams, work effectively in teams, and produce desired results has been recognized as an essential skill set that college graduates should possess [1]. The importance of this skill is even more highlighted in construction and engineering programs in which most of the products or work is usually performed in teams. The overarching goal of this study was to investigate various aspects of teamwork perceived by construction and engineering students. These features were investigated through research questions: 1) how do participants report their teamwork experiences in different settings? 2) what factors do participants consider important to

develop teamwork skills? This paper reports on the data obtained and covers similarities and differences between students based on their gender and race. A cross-sectional survey was designed and distributed among eligible students at Mississippi State University in Fall 2022. The data were gathered, cleaned, and modeled in statistical software packages. Descriptive analyses were conducted to describe the data and reveal potential associations. The findings of the study were discussed to shed light on the student perceptions of teamwork. This paper contributes to the body of knowledge by suggesting practical hints in teamwork design, formation, and development in post-secondary educational programs.

LITERATURE REVIEW

Teamwork Importance

Students' teamwork and collaboration in engineering education have been used as an active learning method in various courses, however, the review of the literature indicates gaps in training students to adequately develop their teamwork skill sets. Gibbard et al. [2] investigated individual and teamwork attributes in undergraduate engineering students. After analyzing the feedback and perceptions of students in engineering programs at the University of Calgary they found a gap existed between teamwork skills students believed they should have and teamwork skills they believed they possessed. They also found that students were receptive to more teamwork initiatives in their engineering education programs. The scope and context of the teamwork are not limited to in-person activities, as many engineering courses are delivered in hybrid or online modes.

Goñi et al. [3] explored the framework for teamwork processes in online and face-to-face environments considering compounding factors such as personal goals, team challenges, and individual/social strategies. While their results showed that in both environments prevalence of goals, challenges, and strategies were similar, online teamwork indicated less group deliberation which could cause challenges for creative thinking. Also, teamwork skill development is not confined to industry or academia as both environments provide opportunities and demand the skill sets.

Herrera et al. [4] investigated similarities and differences between teamwork skills and attitudes provided in academic programs and those required in the industry. They found that although students were often asked to undertake activities as a group, students did not take advantage of interdisciplinary work to their benefit. They also reported differences between the two entities in the areas such as compliance tasks and times, conflict resolution, effective communication, leadership, and collaboration.

Shelestova et al. [5] explored the pedagogical conditions to establish the leadership position of future engineers in academia and stated students' engagement in practical independent activities, modeling of professionally oriented tasks, and nurturing the attitude toward leadership in extracurricular activities are among the factors that facilitate the engineering leadership

positions. An effective teamwork process may play a major role in the project's success and various tools facilitate this role.

Marra et al. [6] explored the role of technology in improving engineering students' collaboration and teamwork skills. They provided a combined pedagogical and technological environment to support collaborative problem-solving efforts in an engineering course. They found a statistically significant relationship between individual student contributions to the collaborative environment and homework and project and exam scores.

Erans and Beneroso [7] investigated the role of Team-Based Learning in the development of teamwork skills in engineering education. They employed a quantitative methodology approach in which 88 third-year engineering students participated in the study. Their analyses showed that Team-Based Learning did not have any significant impact on favoring the promotion of teamwork skills in particular gender groups. Their finding was based on the hypothesis that gender was a demographic characteristic that should not promote a significant advantage towards the development of teamwork skills.

Beddoes and Panther [8] explored the engineering professors' practices and perspectives on the gender and teamwork. They conducted semi-structured interviews with 39 engineering professors to specify their thought processes about gender in engineering and engineering education. They concluded that engineering instructors require methods and tools to help them facilitate gender-inclusive teamwork as current teamwork practices may widen gender inequalities in engineering programs.

Ghannam and Ahmad [9] explored developing teamwork skills among transnational students in engineering and technology programs through a course with 152 students and showed their participants learned more in team-based activities in comparison to the individual study approach, and participants were successful in transforming their teams into more effective learning environments. In addition, most participants preferred team-based projects over individual ones.

Gutierrez et al. [10] studied the perceptions of undergraduate engineering and education students about their interdisciplinary teams while transferring from a face-to-face format to an online delivery mode. They concluded that early establishment and maintenance of roles and routines, synchronous communication tools to facilitate richer communication, and managing time to gain a common understanding of team members' tasks were reported by students as strategies to successfully adapt to new environmental conditions.

González-Fernández et al. [11] investigated whether the self-regulation of teams was useful in promoting teamwork in energy engineering topics over six years and suggested using an initial filtration to form homogeneous teams, instead of unbalanced ones such as teams of friends, teams of the most capable students, etc. They also stated that internal self-regulation mechanisms such as peer assessments resulted in better team performance.

Team Building

While effective teams produce better outcomes, various factors impact the building process or its quality including communication, teambuilding techniques, and team identity. Burchfield et al. [12] evaluated teamwork in undergraduate engineering courses where they offered interpersonal and intercultural communication-based teamwork training. By embedding intercultural communication notions into their course activities, they minimized the number of dysfunctional teams compared to prior experiences and gained positive feedback from students. They also conducted a qualitative analysis of students' self-reflections which revealed an emphasis on the importance of diversity in engineering and teamwork.

Huang et al. [13] explored how teamwork can be improved by using a team process framework. They employed an exploratory case study research approach to evaluate instructors' perspectives in engineering undergraduate programs. They showed various aspects of team processes can be effectively incorporated into team-based activities. These aspects included Transition (team mission and planning, goal specification, and strategy), Action (monitoring progress toward goals, systems monitoring, team support, feedback, and coordination), and Interpersonal (motivation and confidence building, conflict management, and regulating emotions).

Beddoes [14] proposed a conceptual framework and typology for promoting successful interdisciplinary teamwork which included orienting, operating, leveling, proposing, aligning, and structuring artifacts and practices. The study suggested that these concepts can be provided to students as a pre-teamwork intervention to identify, navigate, and avoid challenges that impact effective interdisciplinary teamwork.

Chowdhury and Murzi [15] conducted a literature review on teamwork in engineering education and identify eleven attributes of effective teamwork. These attributes included shared goal & value, commitment to team success, motivation, interpersonal skills, open/effective communication, constructive feedback, ideal team composition, leadership, accountability, interdependence, and adherence to team process and performance. Effective team attributes can be employed to enhance and sustain effective teamwork in engineering, especially at the beginning of team formation.

Tamayo Avila et al. [16] explored methods to improve teamwork in agile software engineering education where they models a framework, entitled, "agile software engineers stick together (ASEST+)" to develop more effective and cohesive teams in software engineering. The ASEST+ framework combined team-based learning, project-problem-based learning, and role-playing game learning strategies in three phases and eight steps. The proposed phases were preparation (setting of the e-learning environment, teams, projects, and introduction activities), implementation (team rules agreement establishment, sprint project deployment, and agile practices application), and adjustment (agreements adjustment and sprint /project conclusion). also, the designed steps included setting the scene: introduction to agile software development, diagnosis of teamwork skills and conflict-handling styles, training on scrum and teamworking

skills: introduction to agile practices, team functioning diagnosis: introduction to automated build and test environments, team rules agreement: team project beginning, team agreement establishment: agile practices application, feedback, and team agreement update. While the steps' second parts are defined as computer engineering jargon, the first part, as implied, can be replicated for team building in engineering subjects. The comparisons of subject and control groups showed that the proposed framework significantly increased the students' positive perceptions of team cohesion, team performance, and team learning [16].

Wolfinbarger et al. [17] explored the role of engineering competition participation, as voluntary teamwork on students' leadership identity development and concluded that competition experiences considerably enhanced the leadership identity in the majority of students as they were allowed to exercise leadership in various ways. They also stated that the lack of consistency between the engineering and leadership identity can help students to build leadership as an engineering practice.

Role of Gender in Teamwork

Despite the emphasis on the role of gender or minorities in engineering education, there are still opportunities to explore teamwork through the lens of gender or minorities. Wolfe et al. [18] explored what teamwork problems women and minorities most frequently encounter in engineering programs and the tools to overcome those problems. In addition to "slacker teammate" which was a common problem reported by participants, female students were significantly more likely than their male counterparts to report issues with feeling like they experienced limited learning. They found that the feeling of being excluded in teams was reported higher by female students and under-represented minorities.

Marinelli et al. [19] explored the development of inclusive teams in engineering programs in Australia through a mixed method. The main goal of the project was to develop the capability among engineering instructors to support their students in practicing and leading gender-inclusive teams. For this purpose, they developed evidence-based resources and delivered them in a face-to-face workshop. They stated team formation, team roles, teamwork experience, and assessment and evaluation are areas that should be clearly addressed to enhance the capabilities of engineering educators in establishing effective gender-mixed teams.

Beigpourian and Ohland [20] conducted a systematized review on the role of gender and race in teamwork in undergraduate engineering classrooms to highlight pertaining factors in the area of women and minorities' teamwork that have been investigated in prior studies. They extracted key terms related to race and gender in engineering Teamwork including collaboration, communication, leadership and self-efficacy, peer evaluation, perceptions of professors and students, team effectiveness and outcome, and team formation. They concluded that female students who had higher motivation for leading teams showed a positive attitude toward collaboration but prefer dialogic collaboration comparing to hierarchical modes. They also stated

that using effective pedagogy for teaming and use peer-led teams benefits minority students in their teamwork activities.

Teamwork and collaboration in engineering programs are increasingly attracting the attention of educational scholars. The interdisciplinary nature of many industries demands teamwork competence at different levels and different forms. In addition, the exponential growth of communication tools, especially, virtual ones, aggravates the criticality of teamwork skill sets. Despite these facts, the opportunity for teamwork educational activities has been largely undeveloped. The unique nature of teamwork experiences has been a hurdle to attaining a comprehensive guideline to form, develop, maintain, and adjourn teams. Each team possesses distinctive characteristics and entails certain capabilities and attitudes. The gap, however, can be filled through status analyses via various viewpoints. Gender and racial minorities have been traditionally underrepresented in engineering programs and therefore their contributions are underestimated or unrealized in educational teams.

METHODOLOGY

The purpose of this study was to explore construction and engineering students' perceptions of different aspects of teamwork in their educational activities. Specifically, the focus of this paper was to highlight similarities and differences between gender and race-based groups. After the review of the literature, a quantitative approach was used for data collection and analysis. A survey was designed based on various features of teamwork and impacting factors that affect the success of team-based educational experiences. The validity and reliability of the survey scale was examined through the 8-step DeVellis model [21]. These eight steps included scope management, item pool generation, measurement format determination, expert review, validation, item inclusion, survey administration, item evaluation, and scale length optimization. The initial survey was then evaluated and modified through expert judgment. The study was assessed by the University Institutional Review Board (IRB) and received Exemption Determination IRB-22-341.

The survey was distributed in Fall 2022 at Mississippi State University in which students from different classes in various eligible programs, especially Construction, Biomedical, and Mechanical Engineering majors participated in a cross-sectional study. Their teamwork experience was considered as their general perception about their prior teams and pertaining aspects such as success, effectiveness, etc. and not necessarily a particular teamwork instance. The initial setting of the study with a confidence interval of 95% and a margin of error of 10% required a sample size of 93 subjects for an acceptable sample representing the population, however, after data gathering, responses were monitored and cleaned, and finally, 232 responses were analyzed. In the next step, statistical software packages such as SPSS and Excel were employed to conduct descriptive analyses and reveal potential associations between gender-based groups (male versus female students) as well as race-based groups (white versus non-white groups).

ANALYSIS

The first section of the survey provided demographic information, which is summarized in Table 1.

Table 1. Demographic Information (Percentage)

Gender	Category	Male	Female			
	Percentage	78	22			
Race	Category	American Indian/Native	Asian	Black/ African American	Hispanic or Latino	White
	Percentage	1	3	3	3	90
Class Level	Category	Freshman	Sophomore	Junior	Senior	Graduate
	Percentage	6	21	19	48	6

The reported hours spent outside the classroom for female and male students were 13.7 and 15.7 hours per week, respectively. Also, the reported GPA for female and male students was 3.53 and 3.27, respectively. In addition, the reported outside of class time for white and non-white groups was 15.3 and 14.3 hours per week, respectively. The reported GPA for white and non-white groups was 3.32 and 3.36, respectively. In the next section, participants were first asked to rate the success of their team-based educational activities (i.e., projects, assignments, etc.). They used a five-level Likert scale to rate the general success (1:Very Low, 5:Very High). The percentage of each level for pairs of female-male as well as white-nonwhite groups are shown in Figure 1 and Figure 2.

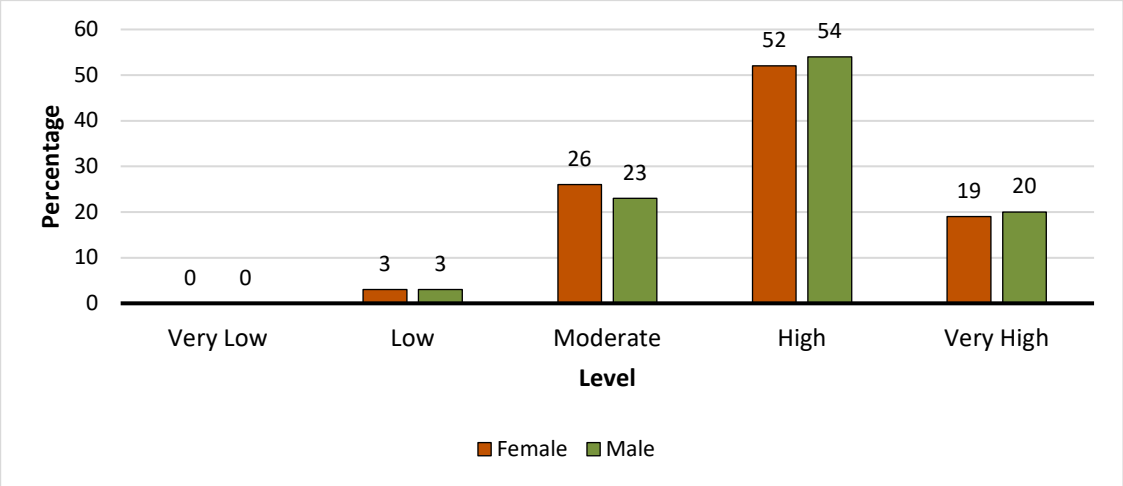

Figure 1. Team success in male and female groups

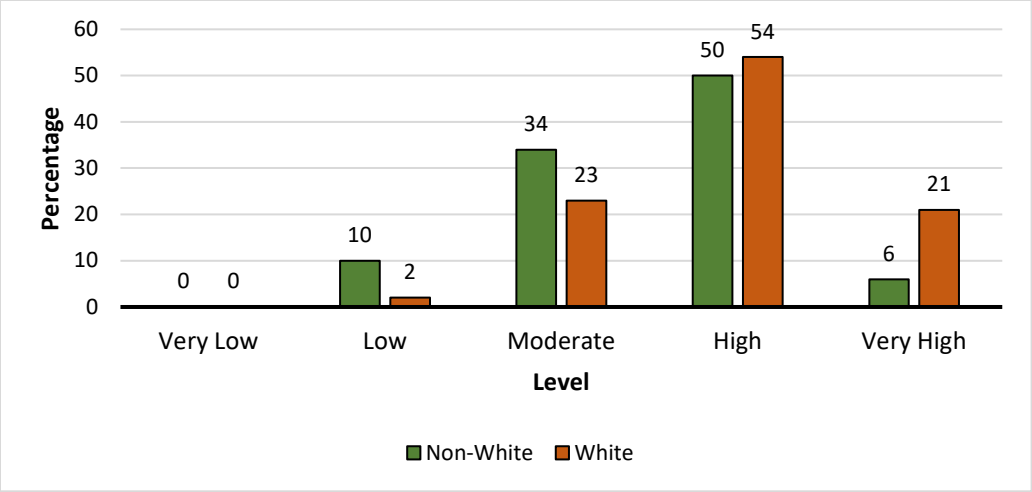

Figure 2. Team success in White and Non-White groups

In the next questions, participants rated the success of teams in which they worked with members from other majors. While the female group and white group reported slightly higher success rates than their counterparts, there were no significant differences between female and male groups as well as white and non-white groups. Also, In the next question, participants were asked to specify the optimum size (number of individuals) of teams for educational activities. The percentage of each team size is shown in Figures 3 and 4. While 4 has been noticeable as the favorite size of the team, male and white groups specified a larger number as their optimum team size. The next questions covered mixed-gender team and their success through the lens of participants. While 24% male students reported no prior experience in mixed-gender teams, only 11% female students expressed no prior mixed-gender experiences. However, the percentages of white and non-white groups were close (22% vs 21%). Also, participants rated the success of their gender-based teams, as shown in Table 2.

Table 2. Mixed-gender team success percentage

	Level	Very Low	Low	Moderate	High	Very High
Gender (%)	**Female**	1	0	19	63	17
	Male	0	2	26	57	14
Race (%)	**Non-White**	1	6	30	56	7
	White	0	1	24	59	15

In the next sections, a series of impacting factors, derived from the literature review, were rated by participants, using a five-level Likert scale. The factors included shared understanding, commitment to participate, mutual benefits, trusting relationships, effective communication,

diversity, co-location, complementary skills, regular feedback by teammates, and regular feedback by professors. The average score of each factor for female versus male groups and non-white versus white groups is shown in Table 3.

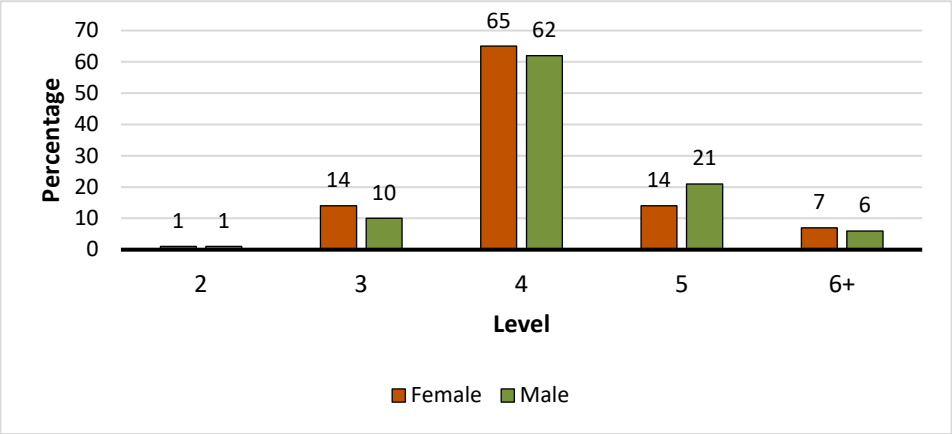

Figure 3. Optimum team size between male and female groups

Table 3. Impacting factor (out of 5)

	Gender		Race	
	Female	**Male**	**Non-White**	**White**
Shared Understanding	3.93	3.73	3.36	3.82
Commitment to Participate	3.78	3.89	3.5	3.91
Mutual Benefits	3.78	3.81	3.45	3.85
Trusting Relationships	3.59	3.71	3.59	3.7
Effective Communication	3.8	3.88	3.55	3.9
Diversity	3.59	3.25	3.41	3.31
Co-location	3.4	3.56	3.32	3.55
Complementary Skills	3.87	3.69	3.45	3.76
Regular Feedback by Teammates	3.85	3.66	3.5	3.72
Regular Feedback by Professors	3.76	3.65	3.55	3.69

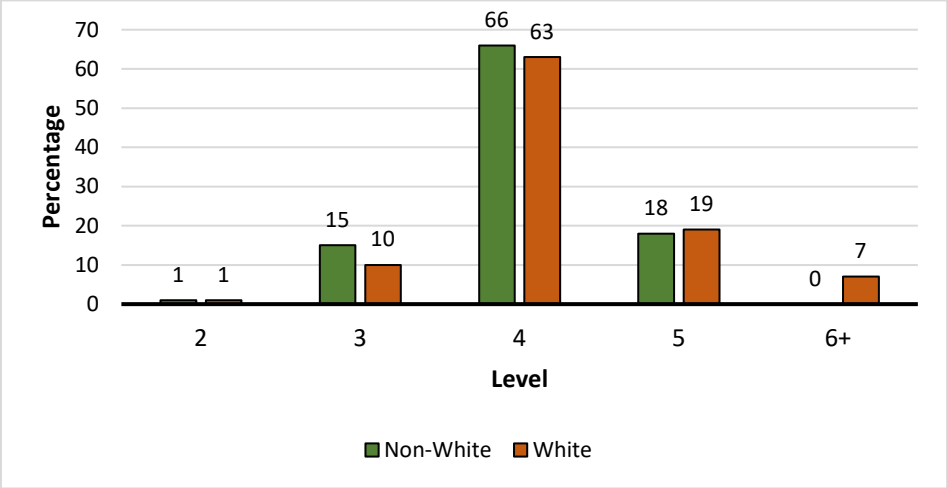

Figure 4. Optimum team size between nonwhite and white groups

Finally, participants rated their level of satisfaction with teamwork and employing it as an educational tool in the rest of their programs. The percentage of each level for the participant groups is shown in Figures 5 and 6.

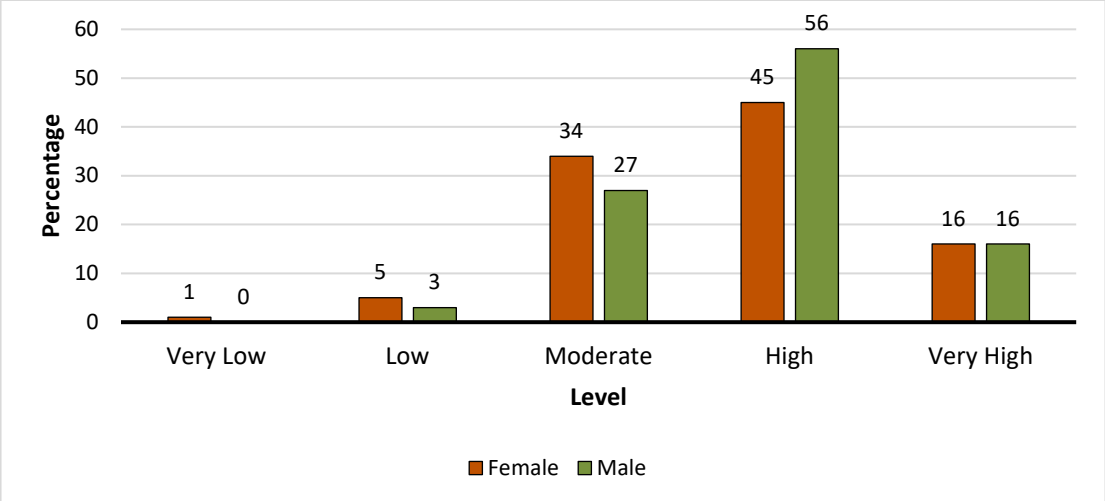

Figure 5. Level of satisfaction between female and male groups

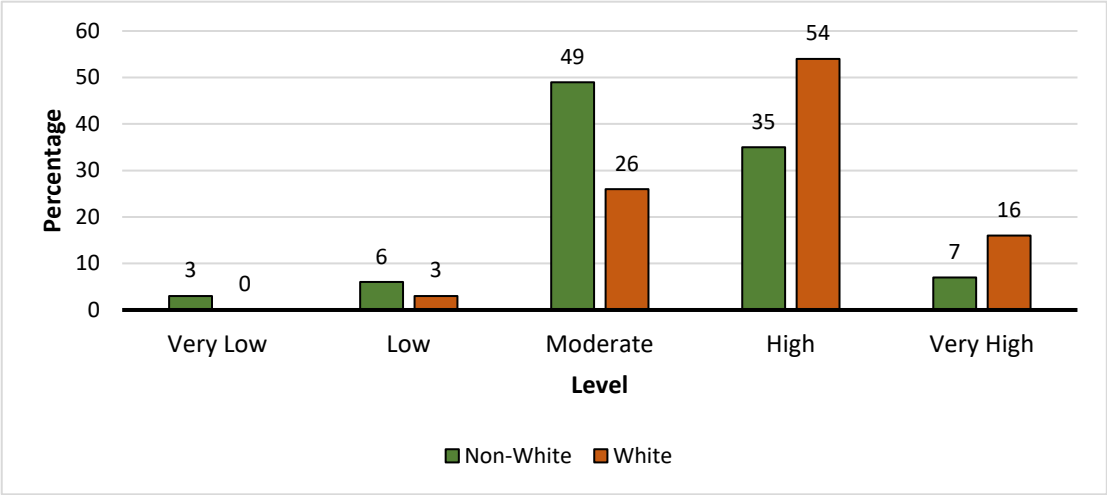

Figure 6. Level of satisfaction between white and non-white groups

DISCUSSION

Teamwork is employed as an active learning method in engineering programs. While the teamwork notion is not new, its application and importance are in current interdisciplinary professional engineering careers. Developing more effective teams in which gender and racial minorities can exhibit their potential and enhance their capabilities adds another layer to the importance of the subject. Teamwork skills are generally developed in group activities, although typically there is no formal training for that, and it is left to students to practice. The current study explored different aspects of teamwork in engineering programs, especially with a focus on the role of gender and race. For this purpose, participants were categorized based on their gender and race, and since the percentage of non-white races was low, it was meaningful to group them together to draw more common similarities and differences. It is also noteworthy that the

imbalance size of racial groups limited applicable statistical analysis. The comparisons between groups indicated that the male group and white group reported a higher score for their team success. While many factors may contribute to this situation, the feeling of unsuccessful teamwork can exacerbate gender and racial disparity. The success of student teams in engineering education should be carefully monitored to ensure a double disparity is not added to underrepresented students. For this purpose, the role of engineering educators to create a balanced team experience for all students is crucial.

Another noticeable point, derived from the analysis, was the size of the teams. The majority of all sub-groups chose a team of four as their ideal size. The preference can help engineering educators when forming a team for class activities. Considering the limited resources available, engineering educators should adjust the scope and requirements of team-based activities to effectively match the team size. Another notable point was the higher percentage of male

students who did not have prior experiences in mixed-gender teams. Similar to the team size, engineering educators may diversify student teams by forming a team with maximum inclusion, when possible. This is important, when the success score of gender-mixed teams, provided in Table 2, is taken into account. Unlike general team success (Figure 1), female students reported a higher success score for gender-based teams than their counterparts. One possible interpretation is that female students perceive diverse teams as more successful. Another notable point was the score of "Diversity" as an impacting factor among groups. In both the male group and the white group, diversity gained the lowest score. However, it was the only factor that its score in the non-white group was higher than the white group. Also, the difference between the scores of male and female groups was higher than that of all other factors. These facts indicate the diversity of teams is considered an important factor and can affect team members' perceptions which in turn may result in unfavorable outcomes or lower success. This fact is observable in the last part (Figures 5 and 6) and can be interpreted as another indication of the necessity of diversity of teams in student educational activities.

CONCLUSION

This paper briefly reported the results of a study covering teamwork in engineering education through the lens of gender and race. The main goal of the study was to explore various aspects of teamwork perceived by students in construction and engineering programs. The literature review of the subject provided key terms and concepts which were later used to develop a survey. A quantitative approach and the obtained data provided a platform for further exploration. The analysis of the data revealed various perceptions toward teamwork. Also, the categorization of participants into female-male and white-nonwhite pairs highlighted similarities and differences.

While the sampled subjects adequately represented the population, the generalization of the findings is not warranted. Additional exploration with larger samples with varied backgrounds and characteristics will improve the reliability of the results. Also, cross-checking the findings with gender and race-based studies may create new hypotheses for additional probes. This study was limited to the study's timeframe and student subjects and content scope; however, the current findings may help engineering educators to better design, form, and develop their student teams in engineering programs.

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