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Teamwork as a Core Competence in Construction and Engineering Education

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TEAMWORK AS A CORE COMPETENCE IN CONSTRUCTION AND ENGINEERING EDUCATION

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Abstract

The specialization of careers in various industries has created a multitude of professional networks that demand close collaboration between parties when working toward a common goal. Additionally, the exponential growth of information technology has evolved with the workflows among various entities involved in a project. Therefore, professionals in various construction or engineering positions must work with their peers closely to form teams. As an interpersonal skill set, the ability to work in teams is gaining more attention in workforce development programs. Construction and engineering programs in higher education should prepare their graduates with ample knowledge and experience in teamworking skills. While the technical and detailed nature of construction and engineering courses influences the possibility of students working in teams, there is still sufficient flexibility in the classroom to facilitate students' collaboration in the form of team projects.

This paper reports on a study conducted in Fall 2022 to explore teamwork among construction and engineering students. The goal of this study is to investigate various aspects of teamwork as perceived by students. In the first phase, a quantitative survey was designed and developed, and a sample of subjects was drawn from students in construction and engineering programs at Mississippi State University. The comparison between these programs produced common themes. The findings of this study contribute to the body of knowledge by addressing key aspects of team-based projects and practices when developing or modifying course components in pertinent programs.

KEYWORDS: Teamwork, Construction, Engineering, Education, Collaboration

INTRODUCTION

Teamwork and collaboration are important aspects of business in the United States. Despite superior technical knowledge and background among individual team members, teams may produce insufficient outputs or even fail due to the inability of team members to work together. While the importance of teamworking skills is well-known among university students, they may graduate without ample experience in working in teams. Along with the theoretical knowledge on major subjects, real teamwork experiences play an important role in student development. Project-based assignments and activities are notable opportunities that students can utilize to improve their teamwork skills. Despite all efforts and practices in construction and engineering educational programs to enhance students' teamwork skills, there is a knowledge gap about students' performance and perceptions of teamwork in non-heterogeneous situations (e.g., other-major teammates, mixed-gender teams, etc.).

Considering the importance of teamwork for students, a research project was generated with the intent to improve teamwork capabilities of future university students. To examine current students' perceptions about teamwork, two groups of construction and engineering students were chosen to participate in a quantitative research project in which they responded to a series of questions about teamwork. Data were gathered, cleaned, and modeled in statistical software, and descriptive analyses were used to illustrate the associations and comparisons between the two groups. Subsequently, similarities and differences between the two groups were described, and potential explanations for the outcomes were discussed. This paper highlights the importance of teamwork as an essential skill set that can be incorporated into various construction and engineering courses in post-secondary educational programs.

LITERATURE REVIEW

Collaboration and teamwork are essential parts of project-based industries. The AEC (architecture, engineering, and construction) industry is heavily dependent on teamwork, as the degree of project success is often determined by collaborative efforts. In a report published by Constructing Excellence [1] a guideline for forming effective teams in the American construction industry was provided in which selecting proper team members, leadership, team meetings, and teamwork matrix (including team identity, shared vision, communication, collaboration, and participation, issue negotiation and resolution, and reflection and self-assessment) were discussed as major factors impacting the productivity of a team. While a team possesses unique aspects, and each aspect imposes a different effect on the structure, processes, feedback loop, and outputs of the team, it is vital to consider major common characteristics when developing a team to perform tasks or, on a larger scale, a project. Koolwijk et al. [2] explored the effects of a no-blame culture on the effectiveness of project-based design teams across different project delivery methods in the construction industry. They concluded that project managers should determine the level of teamwork and encourage collaboration within a project team to acquire a no-blame culture and, consequently, more effective teams.

Akhavan Tabassi et al. [3] explored the effects of training and motivational practices on the efficiency of teams in the construction industry and found that training assignment, perceived importance of training, hygiene factors, and motivating environment can influence the training motivators which can result in higher team performance.
Another aspect of teamwork is the team members' trust and confidence. Buvik and Rolfsen [4] investigated the effects of the history of interactions and prior ties between team members on trust development and stated that early formation of integrative work practices, development of a common philosophy, open communication, early and clear role expectations are four important aspects in teams that considerably affect trust to improve the team results. The trust resulting from effective teamwork can help the entire project organization and professionals. Mitropoulos and Cupido [5] developed a Task Demand-Capability model to connect construction research to a cognitive approach to accident causation and suggested a framework to highlight safety as a feature of the production practices and teamwork processes. In addition, productive teamwork directly impacts employees' satisfaction, as any project's success is considered team members' success. Dhurup et al. [6] studied the synergic relationships between teamwork and job satisfaction through a survey distributed to 178 site managers, administrative and support workers, trained contractors, and construction professionals and showed teamwork contributes positively towards the prediction of job satisfaction.

Another impact of effective teamwork is visible in the outputs of projects. Higher project performance is derived from joint efforts produced by team members. Various studies have investigated the importance and effects of teams on the final outputs, and team building has been considered a crucial process within project-based organizations. Yap et al. [7] explored the factors influencing team dynamics as such factors are crucial for enhancing team performance. They developed a survey questionnaire containing 10 aspects and 25 attributes of teamwork relevant to construction to collect feedback from construction professionals. They found that "project performance," "decision-making capability," and "problem-solving ability" were the three most crucial aspects. In addition, (1) participative engagement and task commitment; (2) team responsibility structure and accountability; (3) a culture of trust and respect; (4) leader's skills and abilities; (5) top management support and (6) synergic working environment were identified as six underlying dimensions, extracted through exploratory factor analysis. These dimensions were provided as indicators for developing policies and processes in team building.

Ellis et al. [8] explored parameters contributing to teamwork effectiveness in construction projects by assessing the effects of complementary person team-fit (CF), supplementary person team-fit (SF), and affective commitment (AC) factors. In this context, Complimentary fit parameters were considered as the individual traits that form socio-cognitive capabilities to perform the job, while supplementary fit parameters (SF) factors were features that foster values in teams. Also, Affective commitment (AC) indicated the extent to which team members feel an attachment to their teams. Through a deductive questionnaire survey and using a structural

equation model (SEM), they concluded that CF, SF, and AC, collectively account for 81% predictive influence on teamwork effectiveness. Therefore, these factors can be embraced to obtain higher team effectiveness. Ahiaga-Dagbui et al. [9] investigated building high-performing and integrated project teams through focus group workshops, semi-structured interviews, and document analysis in which the effectiveness and limitations of a project facilitation model as a coaching tool were evaluated. The model used was designed and developed based on the lessons learned through the execution of more than 120 infrastructure projects. The study showed that the facilitation model supported team behavior development which would result in enhanced team performance. Löfgren and Eriksson [10] explored how collaborative tools impact collaboration which then can impact project performance. They found a positive correlation between collaborative tools (e.g., workshops, joint tasks, and teambuilding activities) and project performance. In another study, Barutha et al. [11] developed a quantitative index that measured the level of collaboration and integration during project delivery. Using a sample of 85 experienced industrial project management professionals, they found a statistically significant correlation between the degree of collaboration and project performance. Also, Fong and Lung [12] explored the effects of cultural and contextual factors such as individualism and power distance, and employee attitudes such as task interdependence and trust in teams in the construction industry. Their analyses showed a positive relationship between trust, either contractual or competence, and team orientation. Also, they stated that as the level of task interdependence expanded, the perception of teamwork increased as well.

The subject of teamwork in construction and engineering programs has been discussed in literature too. While team building, performance, communication, and leadership are essential skill sets that students need to learn and excel in, the subject is not extensively embedded in construction and engineering curricula, and therefore, students' perceptions may not be aligned with the career requirement in a real-world environment. Students' perceptions and attitudes can also directly impact or facilitate teamwork practice in academic programs. Mendo-Lázaro et al. [13] developed an instrument to measure the attitudes of students toward teamwork. The analysis of data obtained from 750 first- and second-year college students revealed the two factors of academic attitudes and social and emotional attitudes. The results indicated an association between expectations of team performance, confidence in classmates, and attitude toward teamwork. In addition, further analysis showed a positive correlation between goals and attitudes. This means participants with more positive attitudes towards teamwork believe it helped them to attain their learning goals. In other words, teamwork was perceived as an approach or tool to reach learning and achievement goals.

He and Yang [14] explored the use of wiki in team collaboration. They studied 83 undergraduate students in 15 teams and found re-processability plays a major role in providing higher collaboration effectiveness by students. The study suggested that instructors should encourage their students to establish an instant communication platform where team members or the system can send instant messages to all and seek immediate peer attention on new ideas or

changes recently made on wikis. They also reported that teams with higher collaborative performance tend to have fewer but longer discussion threads. Thus, providing the ability to discuss on wiki pages rather than on separate discussion forums can increase participation and performance. While various instances indicate the different tools and methods to practice and improve teamwork, the subject and its applicable contexts, structures, and approaches are yet to be further explored.

METHODOLOGY

The main objective of this study is to explore various aspects of teamwork through the lens of students in construction and engineering education programs. The overarching research question was how students perceived teamwork and its outcomes in their course grades. The secondary question was to investigate similarities and differences in the perceptions between construction and engineering students. In the first step, a literature review was conducted to explore different aspects of teamwork, impacting factors, and potential outcomes of effective collaboration in the construction and engineering fields. In the next step and based on the information derived from the review, a list of significant topics was prepared which was then used to define the survey questions. The qualitative method was deemed appropriate as it could cover a larger sample size and maintain appropriate representation among the sample. The survey was refined based on the expert judgment from representatives in the construction and engineering industries. The study was reviewed by the University Institutional Review Board (IRB) and received Exemption Determination IRB-22-341. The survey was distributed to eligible participants, including construction, mechanical engineering, and biomedical engineering students in the 2022-23 academic year at Mississippi State University. A priori analysis was conducted to specify the acceptable sample size representing the population with a confidence interval of 95% and a margin of error of 10%, which resulted in a sample size of 93 subjects. Further, the 8-step DeVellis model was employed to confirm the validity and reliability of the survey scale [15]. A total of 232 responses were collected from the eligible participants. The data was gathered, cleaned, and modeled in statistical software and applicable descriptive and inferential analyses were conducted to summarize the data and reveal potential associations between variables, especially among two groups of construction and engineering students. It should be noted that the construction program at Mississippi State University is not housed in the College of Engineering which diminishes the possibility of students taking similar courses in these groups. Also, the construction program adopted a studio-based teaching model which largely uses project-based learning methods and tools.

RESULTS

In the first section of the survey, students reported their demographic information. Table 1 provides a summary of this data.

Table 1. Demographic Information

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
Major	Category	Construction	Engineering			
	Percentage	46	54			
Class Level	Category	Freshman	Sophomore	Junior	Senior	Graduate
	Percentage	6	21	19	48	6

The average GPA reported by participants was 3.32. Also, participants stated that they spend, on average, 15.28 hours on their assignments and projects outside the class. Participants were asked to rate, on average, what percentage of their class activities (projects, assignments, homework, presentation, etc.) were done through teamwork. A five-level Likert scale was used to quantify the responses. Table 2 shows the percentage of each level between the two groups.

Table 2. Percentage of team-based activities

	0%-20 %	21% - 40%	41% - 60%	61% - 80%	81% - 100%
Construction	6	28	34	26	6
Engineering	8	25	32	27	8

In the next question, participants rated the extent to which they, in general, considered their teamwork experiences successful, using a five-level Likert scale. While general distribution shapes between the two groups were similar, the “high” level percentage in the construction group (61%) was higher than that in the engineering group (47%), as shown in Table 3.

Table 3. Percentage of successful teamwork

	Very Low	Low	Moderate	High	Very High
Construction	0	3	18	61	18
Engineering	0	3	29	47	21

Participants were also asked if they had worked with any collaborators (other majors) in a team for a class activity. Figure 1 shows the percentage of "Yes" and "No" responses in both groups. As shown, most Engineering students stated that they did not have prior experiences with students from other majors in their educational teams.

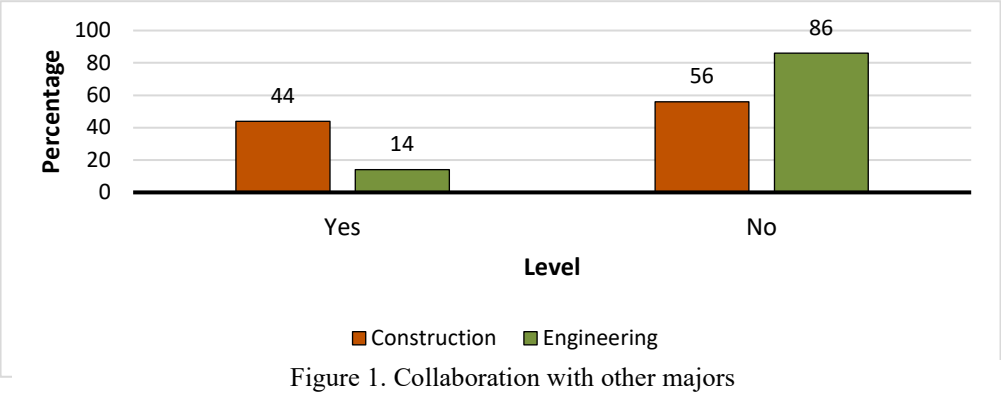

Figure 1. Collaboration with other majors

Those participants whose responses were positive reported the success of their teamwork in working with other majors in general. Five levels were provided to quantify the general success rate. The percentage of each level is shown in Table 4. It should be noted that Construction students have two core courses in common with Architecture students in which they jointly work on design-build projects.

Table 4. Percentage of successful teamwork with other majors

	Very Low	Low	Moderate	High	Very High
Construction	0	5	44	46	5
Engineering	0	5	28	62	5

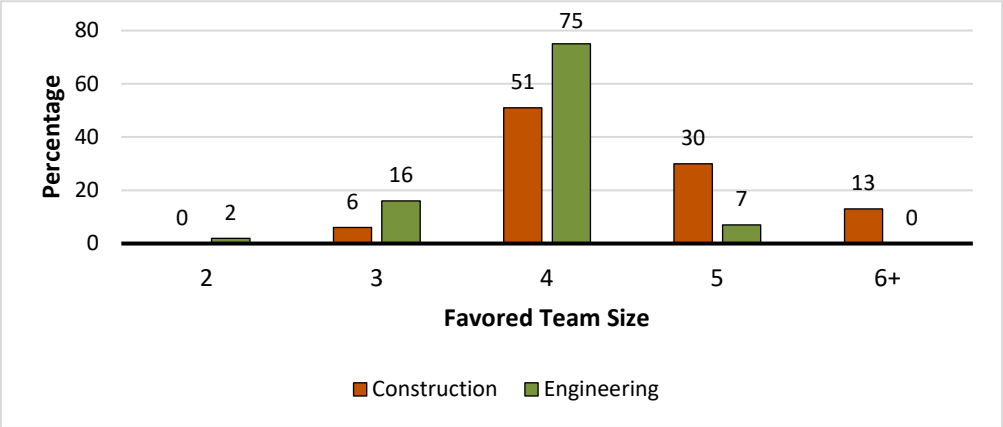

Figure 2. Favored team size

Participants were also asked to specify the ideal size of a team for class activities, based on their previous experiences. As depicted in Figure 2, teams with four members were considerably favored over other variations by both groups.

In the next section of the survey, participants were asked if they had worked in mixed-gender teams for their educational projects and assignment. As shown in Figure 3, about one-third of Engineering students did not work in mixed-gender teams while 95% of Construction students responded positively.

Also, the success rate of mixed-gender teams was expressed with a five-level Likert scale by both groups, as shown in Table 5.

Table 5. Percentage of successful mixed-gender teamwork

	Very Low	Low	Moderate	High	Very High
Construction	0	3	35	50	12
Engineering	0	1	16	66	17

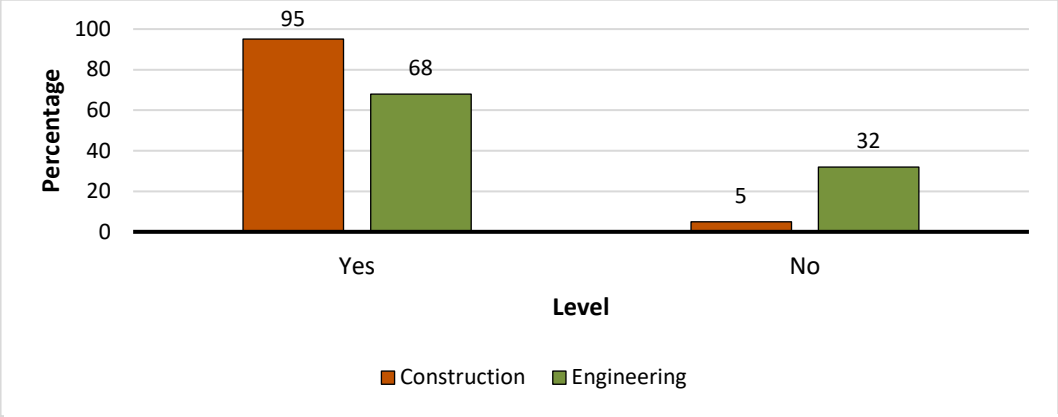

Figure 3. Mixed gender teamwork experience

Also, students rated the impact of various predefined factors on the success of the teamwork using a five-level Likert scale. Figure 4 shows the average score of each factor in both groups. The average scores of impacting factors were generally close between the two groups. However, “Diversity” and “Effective Communication” were rated higher than .04 of the response range. Similarly, “Regular Feedback by Professors” and “Colocation” were expressed with higher importance by Construction students.

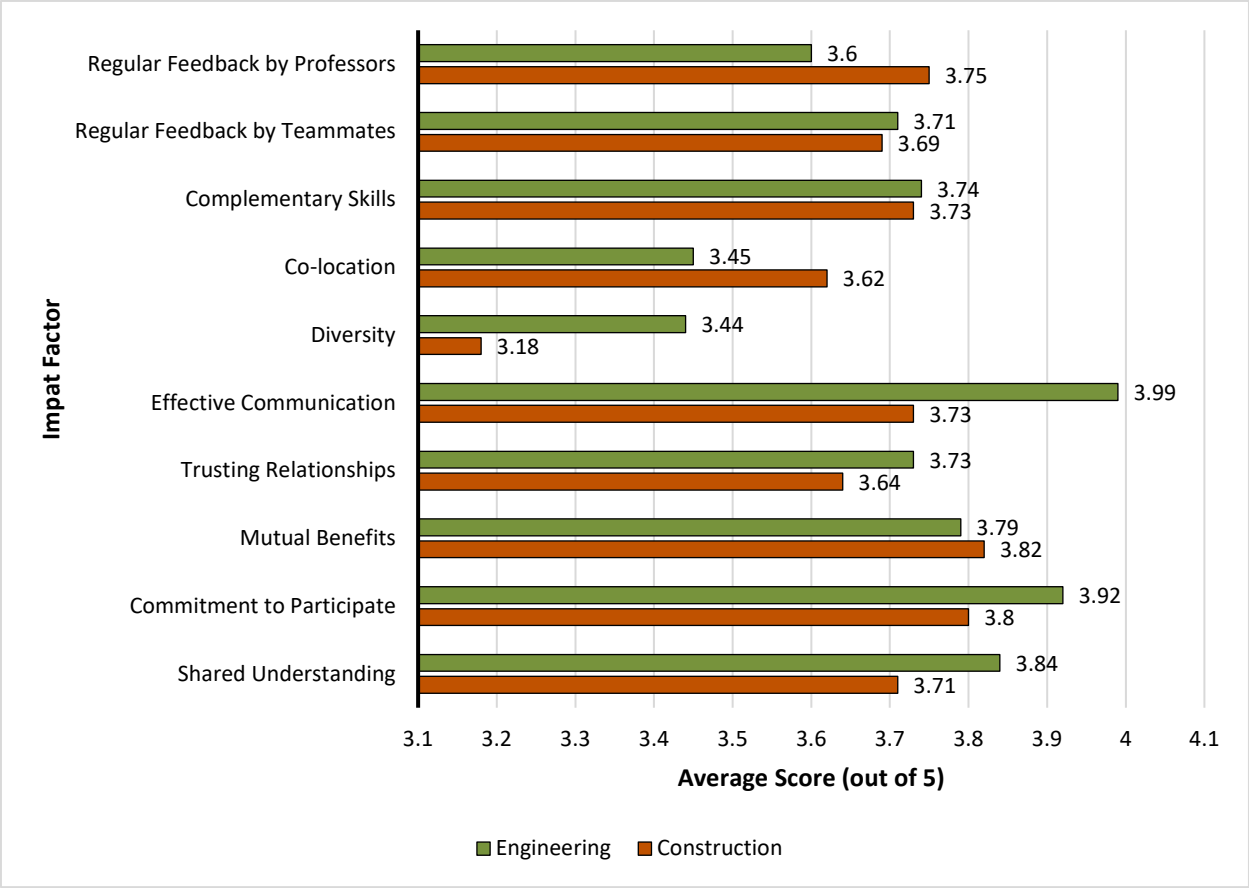

Figure 4. Factor impacting teamwork

Finally, participants rated the extent to which they recommend teamwork for their educational activities or projects. Table 6 shows the percentage of each level in both groups.

Table 6. Percentage of teamwork recommendation

	Very Low	Low	Moderate	High	Very High
Construction	0	2	23	60	15
Engineering	1	4	33	46	16

DISCUSSION

Teamwork and collaboration are among the essential skill sets that all students need to excel in their professional careers. The interdisciplinary nature of many professional positions has increased the criticality of this skill set. In addition, remote working, which was exploited after the COVID-19 pandemic, necessitates collaboration. Thus, teamwork skills should be adequately practiced in academic programs. The construction industry has been naturally dependent on

teamwork as almost all construction work is performed in teams. This dependency is reflected in construction curricula through some team-based courses such as capstone, surveying or other collaborative classes. In addition, project-based courses tend to accommodate team-based activities. A similar situation may exist in engineering programs; however, engineering courses are traditionally defined based on an instructor-learner relationship. Therefore, defining team-based educational activities depends on the instructor's approach. The current study investigated the status of teamwork through the lens of students in construction and engineering educational programs. The preliminary analysis of the data revealed various similarities and differences.

First, the percentage of teamwork activities followed a similar pattern in both groups. The highest percentage in both groups was reported for 41%-60% level. This means students in both groups reported that about half of their educational assignments or projects were performed in team-based formats. Also, while the highest percentage for considering their team-based work success was reported for the "high" level in both groups, the percentage of the construction group (61%) was considerably higher than that of the engineering group (47%). Another noticeable difference between the two groups was the amount of collaboration with other majors. While 44% of construction students stated that they had previous experiences in a team with other majors, only 14% of engineering students had experiences with students from other majors. The possibility of teamwork in general engineering courses that are offered for all engineering majors is an ideal situation to enhance teamwork skills.

Another similarity between the two groups was their favorite team size. The majority of both groups preferred teams of four over other size variations. While there is no explicit reason for this reported preference, the reasons may include the ease and effectiveness of communication, the ability to split the project work among team members and to combine their individual work. Another noticeable point was the difference between the two groups on the mixed gender team experiences. While 95% of construction students reported prior experiences in mixed gender teams, only 68% of engineering students reported such experiences. Considering the fact that the percentage of female students in engineering (30%) was higher than that in construction (11%), the reported percentage of the mixed-gender team experiences may indicate that engineering students were assigned to work in the same gender teams.

Another outcome of the results, shown in Figure 4, is the importance of impacting factors in teamwork, evaluated by students. Both groups showed a similar pattern in rating the predefined factors. In addition, there was no outlier in the reported scores, which means no factor was outstandingly lower or higher than others. However diversity and effective communication gained higher scores by engineering students in pair comparisons, while co-location and regular professors' feedback were rated higher by construction students While these differences are observable, finding causal associations requires further exploration. Finally, both groups expressed a similar attitude toward teamwork. They highly recommended project-based activities in their courses.

CONCLUSION

This paper presented the summary of the first phase of a study conducted on teamwork in construction and engineering educational programs. The main objective of the study was to explore students' perceptions of different aspects of teamwork. The sample representing the population was drawn from construction and engineering programs at Mississippi State University. The comparison between the two groups revealed similarities and differences in the perceptions of teamwork in educational activities. Both groups indicated the importance of teamwork in different forms, including within the major, with other majors, and with mixed-genders, and generally, the success rates of these variations were positive. The results also showed an opportunity for more teamwork in engineering programs. This fact can be translated to various team-based activities in engineering courses that were traditionally structured in an individual-based layout. While the sample size statistically represented the population, the generalization of the outcomes is not warranted. A larger sample size including students from other universities and other research approaches can increase the reliability of the outcome. Further studies may cover factors that impact forming a team, collaboration success, rules governing educational teams, and repeated versus fresh peer effects. Construction and engineering curricula can adopt more team-based activities to further improve collaboration and teamwork skills in students.

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