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Improving Collaboration and Teamwork Skills in Construction Engineering Education: A Case Study from the Final Portfolio Course

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Abstract

The construction industry's complexity demands strong collaboration skills, yet many engineering graduates are unprepared for this challenge. In Chile, only 49.5% of engineering students report developing practical teamwork skills, revealing a critical gap in their training. Addressing this requires fostering key competencies such as collaboration, leadership, communication, conflict resolution, and a strong sense of belonging and shared responsibility. This study aims to determine the impact of collaboration strategies on final-year students' perceptions of teamwork, sense of belonging, and self-efficacy through the analysis of real cases and group dynamics developed in the Final Construction Engineering Portfolio Course. This study adopts a mixed-methods approach, combining quantitative and qualitative data within a quasi-experimental pretest-posttest design. Surveys were applied to all 21 students enrolled in the Final Construction Engineering Portfolio Course during the second semester 2024. Two instruments were used: one focused on teamwork skills and another on sense of belonging and self-efficacy. The participants were organized into seven teams of three students, representing 100% of the course cohort. All activities and data collection were integrated into the regular course schedule. The intervention improved students' perceptions of teamwork, particularly in areas such as responsibility, leadership, and collaboration. Reports of unequal workload distribution dropped significantly, suggesting better team coordination by the end of the course. Students also showed increased autonomy and a stronger sense of belonging, and they valued peer feedback and small-team work more. However, the rise in stress associated with teamwork highlights the importance of integrating collaborative skill development earlier in the curriculum.

Keywords: Collaboration, Construction Engineering, Capstone Project, Teamwork skills, Sense of belonging, self-efficacy

Introduction

The construction industry faces significant challenges due to the complex and multidisciplinary nature of its projects. Effective teams in this sector must coordinate various tasks, from design to execution, often within dynamic and rapidly changing environments. However, recurring issues such as a lack of leadership, poor communication, limited conflict resolution skills, and intercultural differences hinder the integration of diverse and efficient teams [1]. The deficit in collaboration skills has serious consequences, including project delays, increased costs, and reduced work quality [2]. Moreover, the lack of formal training in teamwork skills, often relegated to practical experiences, further increases the likelihood of conflicts and ineffective team management [3].

The need to enhance teamwork and collaboration skills is evident in optimizing performance in academic projects and preparing students for the demands of the professional world [4]. Collaborative and active methodologies that integrate theory and practice and continuous assessment of key competencies are essential to address these challenges. The literature provides extensive evidence supporting strategies such as interactive lecture demonstrations, problem-solving activities, modeling, and teamwork in fostering meaningful learning and student engagement [5, 6, 7 y 8]. As Whitcomb et al. [9] suggest, a positive learning

environment that fosters collaboration in low-pressure contexts strengthens peer interactions and contributes to students' sense of belonging. This sense of belonging plays a crucial role in their performance and engagement, promoting the development of skills, self-efficacy, and the ability to collaborate effectively in teams.

The capstone course within the construction engineering program at a Chilean university provides an ideal setting to address these challenges. This course, comprising 60% team-based work and 40% individual work, enables students to analyze real-world projects from technical and managerial perspectives. Over a semester, students develop critical and practical solutions to problems related to project execution, supervision, and outcomes. As a program guideline, students may enroll in the capstone course alongside a maximum of four additional subjects (three from the 10th semester and one pending course). The allocation of hours for the capstone course is as follows: 11 hours for personal activities, 2 hours for workshops, and 8 hours for theoretical instruction, totaling 21 credits.

Literature review

The successful execution of construction projects relies heavily on teamwork, as their complexity demands the collaboration of individuals with diverse skills. According to Udo-Eyo [10], teamwork effectiveness can be evaluated through various dimensions, including goals, roles, communication, interdependence, performance, and conflict resolution. Sense of belonging plays a crucial role in this context. As Whitcomb et al. [9] noted, external validation and the recognition of achievements directly influence participants' self-efficacy, which positively impacts their ability to collaborate effectively and address conflicts. Similarly, Quezada-Espinoza et al. [11] highlight that an inclusive environment fostering socialization and interpersonal trust strengthens perceptions of interdependence, facilitating conflict resolution and team cohesion.

Teamwork has been widely recognized as a cornerstone for academic and professional success in engineering and science education. Wilson et al. [12] highlighted the transformative potential of teamwork assessments, which provide a more comprehensive educational experience by fostering a diverse range of skills. Despite this, students frequently reported challenges, such as unequal workload distribution within groups, and preferred practical or informal collaborative settings, like laboratory experiences, over formal assessment environments.

The evaluation of teamwork quality has been explored extensively. Herrera et al. [13] identified six key dimensions for assessing teamwork among engineering students: collaboration, leadership, communication, conflict resolution, task completion, and coordination. However, their findings revealed that only 49.54% of engineering students in Chile exhibited effective collaboration, pointing to a significant gap in skill development.

Collaborative and active learning methodologies have proven effective in addressing these gaps. Reyes et al. [14] observed that such approaches promote cooperative environments, fostering a sense of mutual support among students. Similarly, Bringardner et al. [15] emphasized the importance of sense of belonging, mutual responsibility, and respect within effective teams, which are critical for enhancing collaboration and reducing interpersonal conflicts.

Further strategies to improve teamwork include targeted workshops and structured interventions (intentionally designed activities with guided steps, such as prompting

questions, that help students reflect, think conceptually, and reach the appropriate solution to a problem) [16]. Haas et al. [17] demonstrated that workshops focused on team effectiveness significantly enhance teamwork perceptions by ensuring all members are familiar with proposed solutions. At the same time, Miralami et al. [3] warned that a lack of formal training in teamwork skills can exacerbate inequalities, particularly those based on gender and race, negatively impacting students' sense of belonging and team dynamics.

Innovative approaches, such as game-based methodologies, offer additional opportunities to develop critical teamwork skills. For example, Marchiori et al. [2] found that activities requiring students to construct projects with limited resources enhanced their leadership and decision-making abilities and provided a practical context for applying collaborative strategies.

Although various studies have addressed teamwork and transversal skills among university students, a gap remains in their analysis during the final stages of academic training. Most reviewed studies focus on early or intermediate-level students [18, 19] or do not differentiate by academic level [20, 21]. Others, such as Vargas and Carzoglio [22], approach the topic from a regional perspective, specifically in Latin America, and not specifically within the engineering field. This study focuses on final-semester students, offering insight into the advanced development of these competencies and their projection toward formal labor market integration.

This literature review highlights the multifaceted nature of teamwork and emphasizes the need for integrative approaches that combine skill evaluation, active learning, and targeted interventions. Key elements for developing teamwork skills in higher education include leadership, communication, and responsibility, alongside fostering sense of belonging and self-efficacy. By addressing structural inequalities and adopting comprehensive strategies, educational institutions can better prepare students with the collaborative skills essential for academic success and professional readiness.

The aim of this study is to examine how the integration of real-world case analyses and structured group dynamics within a capstone course can enhance students' collaboration skills, improve their perceptions of teamwork, and foster a stronger sense of belonging and self-efficacy in construction engineering education. By focusing on these elements, the study seeks to address skill gaps and prepare students for the demands of the professional construction industry.

Methodology

This study employs a mixed-methods approach, combining quantitative and qualitative data collection at three key points: at the beginning, mid-point, and end of the course. The aim is to analyze how students' perceptions evolve throughout the semester regarding collaboration, sense of belonging, and self-efficacy.

The study follows a quasi-experimental design with a single-group pretest-posttest structure. This design was selected due to the practical constraints of working in an educational setting where random assignment to control and treatment groups is not feasible. All students were enrolled in the same course and participated in the same educational intervention, making a single-group pretest-posttest design the most appropriate and ethical choice.

The independent variable is the implementation of a capstone portfolio, which includes the analysis of real-world construction cases and workshops aimed at fostering collaborative dynamics. The dependent variables are students' perceptions of collaborative work, sense of belonging, and self-efficacy. Data is collected at multiple stages to assess the impact of collaborative activities within the framework of analyzing real construction cases. This design allows for examining changes over time within the same group of students.

Participants and context

The participants were 21 students enrolled in the "Final Construction Engineering Portfolio Course" (an integrative course offered during the final semester of the career), of which 20 were men and one was a woman. The students' ages ranged from 22 to 28 years, with the majority being between 23 and 25 years old. Our university's Construction Engineering (CE) program spans ten semesters and currently enrolls 181 students, with a 10% female participation rate.

Final Construction Engineering Portfolio Course

This course stands out for its collaborative approach, as previously described in [Author (s), 2024]. Students are organized into triads, considering their previous academic performance to create a balanced combination of skills. In a nontraditional format, the course blends theory with practice, focusing on teamwork, analyzing real construction case studies, and presenting weekly topics such as proposal analysis, construction execution, cost analysis, and project management.

The course's practical sessions involve:

- studying the construction processes that are relevant to the projects,
- exploring the possibility of implementing new technologies, and
- analyzing technical and administrative data from real projects tendered publicly.

The course guides students through various tasks, including reviewing technical documents, assessing financial strategies, and optimizing processes. This will help them prepare for real-world challenges in construction engineering. Additionally, the course includes a Community Engagement activity that enhances the practical application of academic theory [Author(s), 2024].

Surveys

To achieve this study's objective, two surveys validated in the literature were utilized: one focused on collaboration skills and the other on sense of belonging and self-efficacy. These instruments are described below.

Survey about collaboration skills (SCS, Appendix B). An adaptation of the instrument developed by Wilson et al. [8] was used to explore students' perceptions and experiences with teamwork in academic settings. This instrument establishes key dimensions for assessing the development of collaboration skills and the factors that positively or negatively influence this process. The survey includes questions about skills fostered through teamwork, such as communication, collaboration, leadership, and time management. It also addresses factors contributing to positive experiences, such as equitable workload distribution and mutual

learning, as well as common challenges, including time management, group dynamics, and unequal participation.

Additionally, the instrument gathers data on students' perceptions of the most effective assessment formats for developing teamwork skills, highlighting a preference for practical activities, such as laboratory sessions and informal study groups, over non-laboratory-based formal assessments. The results obtained from this survey help identify critical areas for improving teamwork practices in educational contexts and designing interventions that optimize collaborative learning in higher education.

Senses on Belonging and Self-Efficacy Survey (SBSS). The SBSS is focused on two critical sociocognitive factors: sense of belonging and self-efficacy. As outlined by Becerra-Cid et al. [22], the survey employed a Likert scale ranging from 1 ("Strongly Disagree") to 5 ("Strongly Agree"), enabling participants to express their level of agreement with statements related to these constructs. These factors are shaped by external influences, such as social and academic interactions within the school environment, including relationships with teachers and peers and institutional services and activities. Sense of belonging reflects how students perceive their integration into and acceptance within the learning environment, while self-efficacy pertains to internal attributes that affect students' identity, interests, and confidence in accomplishing tasks and meeting goals. The survey was administered in a pre-post format, with the initial survey conducted at the start of the semester and the follow-up at its conclusion.

Teamwork activities

To foster collaboration and teamwork skills throughout the course, three structured activities were designed to engage students in progressively complex challenges. These activities aimed to develop team cohesion, enhance decision-making and conflict resolution abilities, and promote reflective practices for continuous improvement. Each activity builds upon the previous one, guiding students from initial team-building exercises to applying collaborative strategies in simulated professional scenarios and, ultimately, reflecting on their collective and individual performance.

Activity 1. Building a Catapult. This activity aims to foster team cohesion and creativity at the start of the semester. Students work in teams of three to construct a functional catapult using limited materials such as popsicle sticks, rubber bands, and plastic spoons. Each team tests their design in a friendly competition, focusing on precision and distance. The activity encourages teamwork, creative problem-solving, and effective communication, setting a strong foundation for future collaboration.

Activity 2 (mid-term): "Building Together: Team Collaboration and Decision-Making Challenge." This activity aims to foster collaboration, decision-making, and conflict resolution within teams by simulating a construction project scenario. Students work in groups to design and plan the construction of a 3m x 3m concrete slab with limited resources. The groups must identify and select the eight most critical resources from a provided list, considering key criteria such as cost, quality, durability, and time efficiency. Participants are assigned specific roles within their team (e.g., project manager, quality assurance lead, procurement officer) and engage in a structured discussion to prioritize their resource choices. The activity emphasizes negotiation and the resolution of potential disagreements to ensure consensus. After completing their selection, each group presents their decisions,

justifications, and conflict-resolution strategies to the class. The exercise concludes with a reflective discussion on teamwork, decision-making processes, and strategies for conflict resolution in the context of construction projects, highlighting the practical implications for professional practice.

Activity 3. "Team Retrospective: Continuous Improvement in Collaboration". This activity aims to encourage students to reflect on their individual and team performance during the semester. Students identify strengths, areas for improvement, and actionable steps to enhance collaboration. Using a structured format, participants write their reflections on post-it notes under three categories: "What We Did Well," "What We Can Improve," and "Ideas for the Future." Teams discuss and organize these reflections, agreeing on at least three specific actions to improve teamwork. The activity concludes with group presentations and a class-wide discussion on lessons learned and strategies for future projects.

Procedure

The implementation procedure involves the application of surveys and thematic workshops at three key points during the semester (Appendix A). The first activity (Activity 1) is conducted at the beginning of the course, before initiating the thesis portfolio. Students complete the Survey about Collaboration Skills (SCS) and Senses on Belonging and Self-Efficacy Survey (SBSS) to establish baseline data during this session. The second activity (Activity 2) is conducted in Week 14, following the academic recess in Week 13, ensuring it does not interfere with other evaluated course activities. This session focuses on conflict resolution and teamwork, complemented by reflective discussions. Finally, the third activity (Activity 3) takes place in Week 17 during the course's closing session. This final session integrates a continuous improvement exercise and a second application of the SCS and SBSS surveys to measure changes and outcomes across the semester. This timeline ensures a progressive development of collaboration, decision-making, and conflict-resolution skills, culminating in reflective practices and data collection to evaluate the intervention's effectiveness.

Data analysis and ethical considerations

Quantitative data were analyzed to evaluate changes in students' perceptions of collaboration, sense of belonging, and self-efficacy throughout the semester. Initial survey responses were processed using descriptive statistics in Excel to identify trends in perceptions about teamwork. For the pre- and post-survey scores from the Sense of Belonging and Self-Efficacy Survey (SBSS), the Wilcoxon Signed-Rank Test was applied to detect significant differences between the two-time points. This non-parametric test was chosen as it is well-suited for small sample sizes and data that do not meet normality assumptions. Only students who completed both the pre- and post-surveys were included in the final analysis.

To ensure the reliability and validity of data collection and analysis, the study employed validated survey instruments adapted from Wilson et al. (2017) [12] and Becerra-Cid et al. (2023) [23], which were applied consistently at the stages. In addition, quantitative data were triangulated with qualitative insights from reflective team discussions and open-ended survey responses. A thematic analysis of these qualitative data further enriched and contextualized the findings.

Ethical considerations were prioritized throughout the study. All participants were given informed consent, ensuring they were fully aware of the study's purpose and procedures.

Data anonymization rigorously maintained confidentiality, and participation was voluntary to ensure that students' involvement did not interfere with their academic responsibilities.

Results

This section presents the study's findings, which aimed to evaluate the impact of collaborative activities within a capstone course on students' teamwork skills, sense of belonging, and self-efficacy. The results are organized into descriptive and inferential analyses, highlighting key student perceptions changes throughout the semester. Descriptive data focuses on the evolution of teamwork skills, factors influencing teamwork experiences, and the development of a sense of belonging and self-efficacy. Inferential analyses, conducted using the Wilcoxon Signed-Rank Test, provide statistical insights into the effectiveness of these activities, examining whether significant differences exist between pre- and post-course measures. These findings offer a comprehensive understanding of the intervention's impact and areas for further exploration.

Teamwork skills

For the four analyzed categories, the greatest changes in perception were observed in *"Teamwork skills are developed through paid jobs undertaken alongside academic studies,"* as shown in Figure 1. Regarding *"Teamwork skills are essential for a career in construction engineering,"* 100% of the students valued teamwork skills as essential for professional practice, maintaining a consistent rating of 100% at both the beginning and the end of the course.

In contrast, when asked whether these skills are developed during their academic program, most students agreed; however, the initial measurement of 90% (19/21) showed slightly better results than the final measurement of 85% (18/21), as illustrated in Figure 1b.

On the other hand, students valued the contribution of extracurricular activities as significant for developing collaborative skills, with an increase from 80% (17/21) to 90% (19/21) in this category. Finally, in d), the perception of the contribution of paid jobs undertaken alongside academic studies to the development of teamwork skills increased from 62% (13/21) to 76% (16/21). This last result may suggest that students recognize the value of real-world work environments in fostering teamwork skills, as they have experienced such contexts, at least during their curricular internships on-site. However, they may not necessarily regard these experiences as part of formal academic activities.

Skills and factors that influence teamwork experiences

In the domain of perceptions regarding skills and factors that influence teamwork experiences, students were evaluated across four dimensions, where they were asked to select five statements that best represented their experiences. Below, the responses and their evolution between the course's beginning and end are presented.

For the statement *"Indicate which skills you believe are developed when working in a group,"* a frequency table (Tab. 1) illustrates the most popular responses, highlighting key changes over the semester.

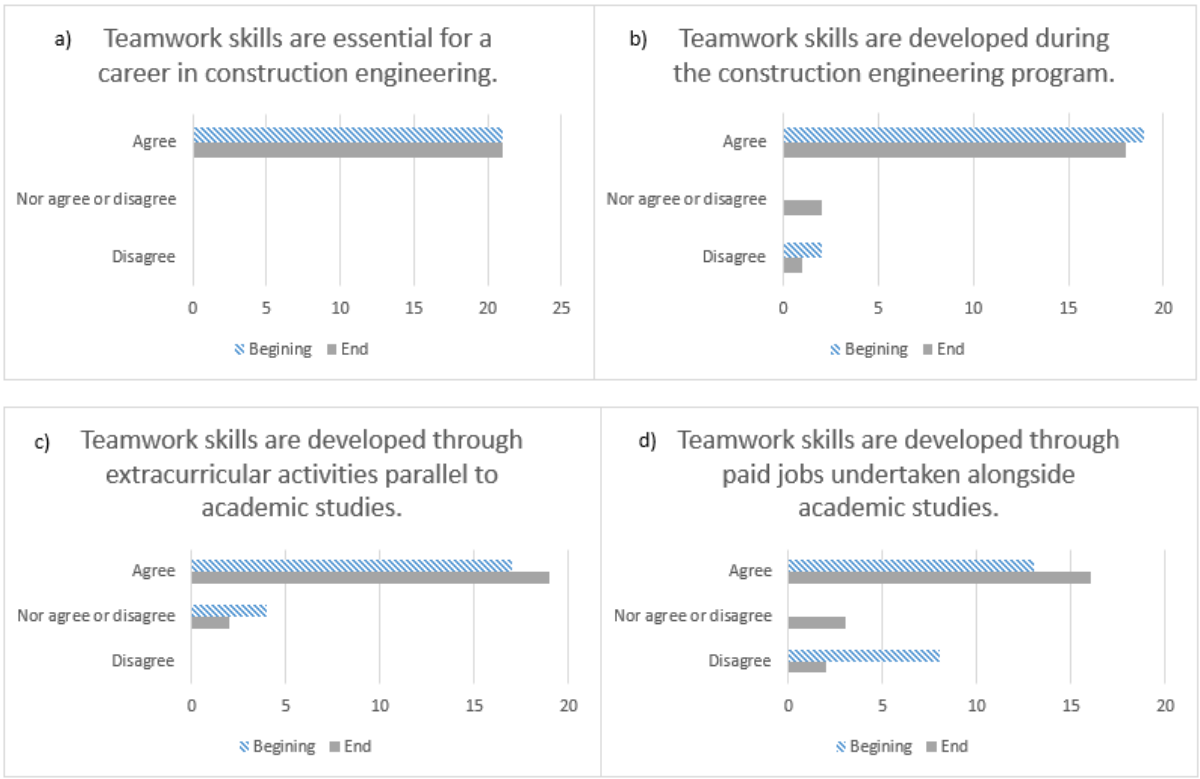

Figure 1. Perception of teamwork skills.

Table 1. Changes in students' perceived relevance of skills developed through teamwork.

Skills	**Frequency within the Top 5 Preferences**		**Differences Final-Beginning**
	Beginning	Final	
Problem-solving	18	9	-9
Responsibility	16	12	-4
Communication skills	16	8	-8
Collaboration skills	15	10	-5
Leadership skills	14	12	-2
Debate skills	10	12	2
Time management	9	10	1
Negotiation	4	3	-1
Self-management	3	2	-1

At the beginning of the course, students identified the most relevant skills developed through teamwork as: 1. Problem-solving, 2. Responsibility, 3. Communication, 4. Collaboration, and 5. Leadership skills. By the end of the course, students ranked the top five skills as: 1. Responsibility, 2. Leadership skills, 3. Debate skills, 4. Collaboration skills, and 5. Time management. Notably, only Debate skills and Time management increased in frequency over the semester.

The results indicate that Responsibility and Collaboration consistently remained among the most frequently mentioned skills throughout the course. However, following the capstone

experience, Debate and Leadership skills emerged as more prominent, alongside the notable rise of Time management, which surpassed other relevant skills.

When reviewing factors that contribute positively to teamwork (Tab. 2), as indicated by the statement *"Indicate which of the following factors you believe have contributed to a positive teamwork experience during your studies,"* students initially identified the following factors as most prevalent: 1. Sharing the workload among team members, 2. My teammates teaching me content and skills, 3. Teaching my teammates new content and skills, 4. The final product is better than what could be done individually, and 5. Working with friends. These factors also remained the most recognized in the final survey. However, perceptions of relevance for four out of the five factors decreased slightly by the end of the course, with only Working with friends showing a marginal increase in mentions.

Table 2. Changes in perceived factors contributing to positive teamwork experiences.

Factors	Frequency within the Top 5 Preferences		Differences Final-Beginning
	Beginning	Final	
Sharing the workload among team members	20	13	-7
My teammates teaching me content and skills	19	12	-7
Teaching my teammates new content and skills	18	17	-1
The final product is better than what could be done individually	14	13	-1
Working with friends	13	14	1
I feel more motivated when working with others	12	10	-2
Meeting new people	8	6	-2
I have not experienced any positive aspects of teamwork	0	6	6

Table 2 shows that only 2 out of the 8 statements increased in value, with a notable emergence of the response *"I have not experienced any positive aspects of teamwork,"* which rose from 0% to 29% (6/21). This finding may suggest a decline in students' positive perception of teamwork over the course.

Regarding the statement, *"Please indicate which of the following factors you believe may have contributed to a positive outcome in your evaluations when working in a group,"* students initially identified *"Receiving feedback from my team members"* as the most frequent response. This preference remained consistent at the end of the course. The statements showing the most significant evolution were *"Small number of people in the team (<3)"* and *"Unscheduled teamwork outside of class hours (>1 month),* as illustrated in Table 3.

This aspect was initially considered highly significant regarding the relevance of having a tutor or professor guide teamwork to achieve good results. However, by the end of the semester, it dropped to 5th place, with 48% of mentions, remaining within the top five but showing a notable decrease. Regarding factors negatively affecting teamwork (as shown in Table 4), the most significant decreases were observed in collaboration and workload distribution items. However, both remained among the five most frequently mentioned factors. Four of the five most popular statements at the beginning of the semester remained in the top group by the end:

1. One or more team members do not contribute / Unfair workload distribution.

2. Time management among team members.
3. Relying on other students' work for a final grade.
4. Not being able to do the work the way I would like.

A notable increase was observed in the statement *"It is more stressful than working alone,"* which rose from 11th place initially to 5th place by the end of the semester.

Table 3. Changes in perceived factors contributing to positive teamwork outcomes.

Factors	Frequency within the Top 5 Preferences		Differences Final-Beginning
	Beginning	Final	
Receiving feedback from my team members.	16	21	5
Having a tutor or professor supervise and guide the teamwork.	16	10	-6
Being evaluated both individually and as a team.	15	9	-6
Incorporating a collaborative experience.	13	9	-4
Having regularly scheduled class time for teamwork.	11	7	-4
Being able to work with friends (choosing team members).	9	5	-4
Small number of people in the team (< 3).	8	17	9
Being evaluated on the ability to collaborate.	7	5	-2
Unscheduled teamwork outside of class hours.	6	15	9
Having plenty of time to complete the project (> 1 month).	3	11	8
Working without supervision (no tutor or professor).	1	3	2
Large number of people in the team (> 3).	0	3	3

Table 4. Changes in perceived factors negatively impacting teamwork experiences.

Factors	Frequency within the Top 5 Preferences		Differences Final-Beginning
	Beginning	Final	
One or more team members do not contribute / Unfair distribution of the workload.	20	12	-8
Time management among team members.	17	20	3
Relying on other students' work for a final grade.	17	14	-3
Trying to schedule team meetings.	12	8	-4
Not being able to do the work the way I would like.	10	14	4
Interpersonal conflict.	8	7	-1
Working with people I do not like.	6	3	-3
Team members are a distraction and it is difficult to concentrate on the work.	6	4	-2
Lack of class time assigned.	4	7	3
Peer evaluation.	3	3	0
It is more stressful than working alone.	2	9	7
I have not experienced any negative aspects of teamwork.	0	4	4

The high valuation of time management among team members as a relevant factor stands out, moving from second to first place in mentions. A positive outcome is the decreased importance given by students to the statement *"One or more team members do not contribute / Unfair distribution of the workload."* Initially, 20 out of 21 students perceived that the workload distribution might not be equitable, while in the final measurement, only 12 students included it among their preferences, reflecting a decrease of 8 responses.

Sense of belonging and self-efficacy

In this study, we analyzed quantitative data using SPSS®. We used the Wilcoxon Signed-Rank Test to compare pre- and post-survey scores from the Sense of Belonging and Self-Efficacy Survey (SBSS). This test, suitable for small samples, is an alternative to the paired t-test when data do not meet normality assumptions. Only participants with pre-and post-test scores were included, resulting in a final sample of 17 students.

To begin, we paired pre- and post-survey outcomes for comparison (Figures 2). We grouped responses of 4 (Agree) and 5 (Totally Agree) to simplify the analysis of shifts in students' sense of belonging and self-efficacy. The Wilcoxon test results, processed in SPSS, helped identify significant median differences between pre-and post-survey scores in non-normally distributed data.

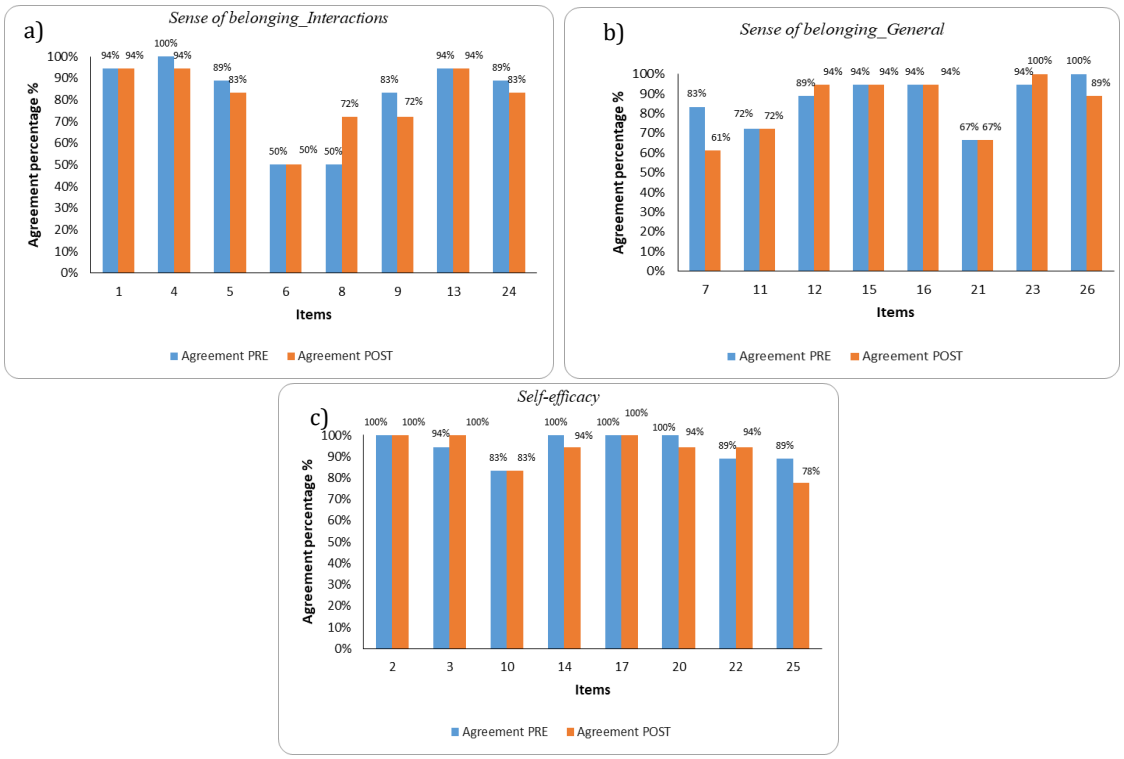

Figure 2. Comparison of pre- and post-survey agreement levels on sense of belonging and self-efficacy.

In Fig. 2a, the most notable changes in this category include item 7 (*I feel that I belong to this university.*), where agreement decreased from 83% (pre) to 61% (post). Additionally, item 26 (*The students at this university are friendly toward me.*) showed a decline, with agreement dropping from 100% (pre) to 89% (post), suggesting a slight decrease in students' perceptions of peer friendliness over time. These results emphasize that while most items remained stable

or showed improvement, certain aspects experienced slight declines, necessitating further exploration of the underlying factors influencing these perceptions.

In Fig. 2b, the most notable changes include Item 8 (It would be easy for me to join study groups with other students if I wanted to), where agreement decreased from 83% (pre) to 72% (post). Similarly, Item 24 (I feel comfortable asking questions in my classes) showed a slight decline, with agreement dropping from 89% (pre) to 83% (post). The decline in agreement for Item 8 and Item 24 suggests a potential decrease in students' confidence regarding their ability to connect with peers and actively participate in class discussions. This may indicate underlying challenges in fostering sense of belonging and inclusivity, highlighting the need to explore strategies that strengthen peer interactions and classroom engagement.

In Fig. 2c, notable improvements in self-efficacy include Item 3 (*I can generally handle situations that come my way.*): Agreement increased from 94% (pre) to 100% (post). Item 22 (*I can remain calm when facing difficulties because I trust my problem-solving abilities.*): Agreement rose from 89% (pre) to 94% (post). The increase in agreement for Item 3 and Item 22 reflects a positive shift in students' confidence in handling challenges and trusting their problem-solving abilities. These results suggest that the course activities have enhanced students' self-efficacy in managing tasks and overcoming difficulties.

Wilcoxon Test

Inferential statistical tests were conducted to evaluate the impact of collaborative activities on students' sense of belonging and self-efficacy. The results from the Wilcoxon Signed-Rank Test provide insights into the effectiveness of the interventions implemented throughout the course. If the p-value is 0.000 ($p=0.000<\alpha=0.05$), there is sufficient evidence to reject the null hypothesis, indicating that collaborative activities within the framework of the capstone portfolio improve the sense of belonging and self-efficacy among construction engineering students.

Hypotheses

Null Hypothesis (H0): Collaborative activities within the framework of the capstone portfolio do not increase students' sense of belonging or self-efficacy.

Alternative Hypothesis (H1): Collaborative activities within the framework of the capstone portfolio increase students' sense of belonging and self-efficacy.

For Sense of Belonging_Interactions:

- Test statistic $Z=-0.402Z$, $p=0.688$
- Decision: Fail to reject H0. There is insufficient statistical evidence to conclude that collaborative activities within the framework of the capstone portfolio increase students' sense of belonging in interactions.

For Sense of Belonging_General:

- Test statistic $Z=-1.990Z$, ***p=0.047*** *(mean pre=4.324, mean post= 4.229)*
- Decision: Reject H0. While there is a statistically significant difference between pre- and post-survey scores, the post-survey mean is lower than the pre-survey mean. This indicates that collaborative activities within the

framework of the capstone portfolio did not increase students' sense of belonging and may have slightly reduced it.

For Self-Efficacy:

- Test statistic $Z=-0.158Z$, $p=0.875$
- Decision: Fail to reject H0. There is not enough statistical evidence to conclude that collaborative activities within the framework of the capstone portfolio increase students' self-efficacy.

Discussion

The students in this study highly valued the ability to work in teams, develop strategies to solve conflicts and communicate effectively. This is recognized not only as a key factor for academic success but also as a critical competency for professional performance in future projects, consistent with the findings of Li et al., Marchiari et al., and Rokooei et al. [1-2, 4]. Moreover, students demonstrated a positive attitude toward respectful peer feedback, particularly within small groups and when working with friends. This reinforces Whitcomb et al.[9]'s assertion of the importance of self-efficacy and a sense of belonging in achieving meaningful learning. Similarly, this aligns with Bringardner et al. [15], who emphasize mutual respect and responsibility as key elements for team effectiveness, with feedback being a fundamental tool for creating a supportive environment.
Teamwork is a core requirement in the construction industry and essential for achieving academic and professional success. Responsibility, leadership, and debate were identified as fundamental skills when working in teams, consistent with Udo-Eyo's findings [10], which highlight these skills as enablers for improving team communication and conflict resolution. Additionally, the results align with Herrera et al. [13], who identified key aspects for evaluating teamwork quality, such as collaboration, leadership, communication, and coordination. The students' concerns regarding unequal contributions within group members are consistent with Wilson's research [12] and present an opportunity to incorporate self-management tools to enhance individual participation and contributions.

Shadravan's study [21] asserts that measurement tools for collaborative work often neglect aspects related to communication and conflict resolution; however, this study incorporates these dimensions from the students' self-perceptions. Additionally, Jiménez et al. [20] and Vargas and Carzoglio [22] highlight the disparity between students' expectations and employers' perceptions. Within this framework the present study examines how students evaluate their skills in teamwork through a simulated work experience, a model that may more effectively align with employers' perspectives on real-world work environments.

The increase in positive perceptions of teamwork developed through paid jobs undertaken alongside academic studies is consistent with findings in science students, which may also be related to a stronger sense of belonging and greater self-efficacy. Effective collaboration can be influenced by external validation and recognition of achievements, as suggested by Miralami and Haas [3,17] in their respective studies.
The decreased importance of having a tutor could be interpreted as students achieving a certain level of autonomy as they near graduation. However, having a tutor or instructor remains among the most relevant factors for most students. This decline in perceived importance might be linked to their growing self-efficacy, which allows them to feel more confident in conflict resolution and decision-making within their teams. This aligns with

active learning methodologies that promote responsibility, autonomy, and collaboration skills, as highlighted by several authors.
A contradictory result compared to the literature is some students' perception that teamwork is more stressful than working individually. This could be influenced by an initial lack of collaborative skills, which must undoubtedly be addressed with greater emphasis throughout the program's curriculum. Various methodologies should be implemented to ensure better integration into diverse teams, both in academic settings and in the professional practice required by the construction industry.

Conclusions

This study aimed to examine how integrating real-world case analyses and structured group dynamics within a capstone course could enhance students' collaboration skills, improve their perceptions of teamwork, and foster a stronger sense of belonging and self-efficacy in construction engineering education. A mixed-methods approach was used, combining quantitative data collection at three key points (beginning, mid-point, and end of the course) to analyze changes in students' perceptions throughout the semester. A quasi-experimental pretest-posttest design was implemented, using the capstone portfolio as an intervention to foster collaborative dynamics, while measuring outcomes related to teamwork, belonging, and self-efficacy.

At the end of the capstone course, students recognized the fundamental importance of collaboration and teamwork skills for their professional performance. While 85% of students believed these skills were strengthened through academic activities, 90% indicated that extracurricular activities also contributed significantly to their development. Notably, the perception that teamwork skills are developed through paid jobs undertaken alongside academic studies increased from 38% at the beginning of the course to 76% by its conclusion.

Among the teamwork skills strengthened during the course, students emphasized responsibility, leadership, and debate skills as equally relevant. These were followed closely by collaboration and time management. Factors contributing positively to teamwork remained consistent between the beginning and end of the course, with the most frequently mentioned being sharing the workload among team members, learning and teaching content and skills from peers, achieving a superior final product than could be done individually, and working with friends. Additionally, the factor *"Teaching new content and skills to my peers"* reached 81% agreement by the end of the course, consistent across both time points of measurement.

Considering factors positively influencing teamwork evaluations, the most relevant *was "Receiving feedback from team members,"* followed by working in small teams (<3 members) and time spent outside of class preparing submissions. These last two factors showed significant increases of 38% between the initial and final measurements, reaching 80% and 71%, respectively, in the final assessment.

Regarding the relevance of having a tutor or guide for teamwork and achieving good results, this factor was highly valued at the beginning of the course but dropped to fifth place by the end of the semester. This decline may indicate that students developed greater autonomy as they neared graduation, which is undoubtedly a positive outcome.

In terms of factors negatively impacting teamwork, the most notable change was observed in *"One or more team members do not contribute / Unfair distribution of the workload,"* which dropped from being the most mentioned factor at the beginning of the course (95%) to 57%

by the end. This suggests that students were able to improve task distribution among team members over time.

However, a significant increase was observed in the *statement "It is more stressful than working alone,"* which rose from 11th place in the initial assessment to 6th place in the final, with a 33% increase. This finding highlights the need to reinforce collaborative skills earlier in the curriculum to reduce stress associated with teamwork and ensure better integration into diverse teams, both in academic and professional settings required by the construction industry.

For practical applications of teamwork implementation, structured actions from the outset are essential, providing measurable tools from diagnosis to outcomes and integrating them into learning outcomes and assessment. Emphasizing the tutor's role as a guide and training faculty in peer learning strategies is both necessary and highly valued by students.

The main limitations of this study include the small sample size of 21 students, which limits the generalizability of the findings, and its focus on a single university's construction engineering program, reducing applicability to other contexts. The quasi-experimental design without a control group makes it challenging to isolate the impact of the capstone portfolio intervention from external factors. The absence of qualitative data further limits a deeper understanding of students' experiences, and the findings' specificity to construction engineering education may not fully extend to other disciplines. Future research could address these limitations by expanding the sample size, incorporating qualitative methods, and examining long-term outcomes across diverse academic contexts.

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Appendix A. Semester activities description (2024-2)

Week	**Activity**
W1	Course introduction and group assignments. Catapult dynamics. Surveys SCS and SBSS
W2	Presentation of proposed projects. Compliance with urban regulations study. Scope and Purpose of the project to be selected
W3	Itemization/Worksite setup/Organizational chart.
W4	Environmental considerations.
W5	Structural work and finishing work quantity takeoff
W6	Labor productivity and material estimate.
W7	Unit price analyses, Direct costs budget, General expenses and profit estimation.
W8	Programation: Project baseline schedule
W9	Contingency analysis and Rescheduling with contingencies.
W10	Baseline schedule/Contingency schedule/Compensated schedule through industrialization.

W11	Project improvements (technological, industrialization, sustainability, and safety aspects).
W12	Income statement, labor flow, and cash flow.
W13	Break
W14	Mid-course activity: Conflict resolution and Surveys SCS
W15	Final group presentation and project book.
W16	Consultations for report delivery and exam, evaluation rubrics, and RA.
W17	Final activity: Continuous improvement based on personal performance and team contribution. Surveys SCS and SBSS

Appendix B. Survey about collaboration skills

Dimenssion	Item	Options
Teamwork Skills Perceptions (4)	1) Teamwork skills are essential for a career in construction engineering.	5. Strongly agree 4. Agree 3. Neutral 2. Disagree 1. Strongly disagree
	2) Teamwork skills are developed during the construction engineering program.	5. Strongly agree 4. Agree 3. Neutral 2. Disagree 1. Strongly disagree
	3) Teamwork skills are developed through extracurricular activities parallel to academic studies.	5. Strongly agree 4. Agree 3. Neutral 2. Disagree 1. Strongly disagree
	4) Teamwork skills are developed through paid jobs undertaken alongside academic studies.	5. Strongly agree 4. Agree 3. Neutral 2. Disagree 1. Strongly disagree
	5) Indicate which skills you believe are developed when working in a group. Select the 5 you consider most important.	Debate skills Self-management Time management Responsibility Problem-solving Negotiation Leadership Collaboration Communication
Factors that Contribute to a Positive Teamwork	6) Indicate which of the following factors you believe have contributed to a positive teamwork experience during	● I have not experienced any positive aspects of teamwork. ● The final product is better than what could be achieved individually.

Experience	your studies. Select the 5 you consider most important.	• I feel more motivated when working with others. • Teaching my teammates new content and skills. • My teammates teaching me content and skills. • Working with friends. • Sharing the workload among team members. • Meeting new people.
Factors that Contribute to Positive Outcomes in Team Assessments	7) Please indicate which of the following factors you believe may have contributed to positive outcomes in your assessments when working in a group. Select the 5 you consider most important.	• Large team size (> 3 members) • Working without supervision (no tutor or teacher) • Having plenty of time to complete the project (> 1 month) • Receiving feedback from team members • Teamwork outside of scheduled class hours • Being evaluated on collaboration skills • Incorporating a collaborative experience • Having a tutor or teacher to supervise and guide teamwork • Being able to work with friends (choosing team members) • Small team size (< 3 members) • Being evaluated individually as well as in a team • Having regularly assigned class time for teamwork
Negative Aspects of Teamwork	8) Please indicate which of the following negative aspects of teamwork tasks you have experienced. Select the 5 you consider most important.	• I have not experienced any negative aspects of teamwork. • Team members are a distraction, making it difficult to focus on the work. • Peer evaluation. • Interpersonal conflict. • Working with people I do not like. • Not being able to do the work the way I would prefer. • It is more stressful than working alone. • Lack of assigned time in class. • Time management issues among group members. • Relying on other students' work for a final grade. • One or more group members do not contribute/unfair distribution of the workload. • Trying to schedule team meetings.