

# Collaborative Learning in Technical and Vocational Education and Training: A Mixed-Methods Quasi-Experimental Study in Chile

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## Abstract

This study aimed to evaluate the effects of a structured collaborative learning (CL) intervention on the development of key collaborative competencies among female students enrolled in a short-cycle Technical and Vocational Education and Training (TVET) program in Chile. A quasi-experimental, mixed-methods design with non-equivalent control and experimental groups ( $n = 37$ ) was implemented. Quantitative data were collected using a locally adapted Cooperative Learning Questionnaire, while qualitative insights were obtained through open-ended digital surveys. The four-session intervention, delivered once per week, yielded statistically significant pre-post gains in social skills, group processing, and promotive interaction, alongside positive yet non-significant trends in positive interdependence and individual accountability. Thematic analysis corroborated these findings, revealing enhanced communication, empathy, teamwork, and professional readiness among participants. Collectively, the results provide empirical evidence for the pedagogical relevance of CL in TVET, underscoring its capacity to foster both socio-emotional and professional competencies. However, the modest sample size and short intervention period limit generalizability, highlighting the need for further research on gender dynamics, scalability, and digital integration across diverse TVET contexts.

## 1. Introduction

Education institutions worldwide are navigating profound social, technological, and labor transformations characteristic of the Fourth Industrial Revolution, prominently driven by digitalization, automation, and globalization (Boltsi et al., 2024; Ciolacu et al., 2023; World Economic Forum [WEF], 2015). These global shifts necessitate a fundamental realignment of educational paradigms, requiring a move from traditional instructor-centered models toward dynamic, student-centered pedagogies that cultivate critical thinking, collaborative problem-solving, creativity, digital literacy, and emotional intelligence (Suyato et al., 2024; Wu et al., 2024; Tadesse et al., 2024). International frameworks, including those of the WEF (2015), consistently identify these transversal competencies as essential for academic success, employability, productivity, and social mobility (Mulder, 2017).

Despite widespread international consensus on these educational priorities, Technical and Vocational Education and Training (TVET) institutions continue to encounter substantial barriers in adapting their pedagogical practices to evolving skill requirements. Instructor-dominated methodologies and passive knowledge transmission remain prevalent, impeding the development of workplace-relevant skills demanded by Industry 4.0 (Hossain et al., 2019). These difficulties are exacerbated by structural constraints such as limited instructional time, insufficient teacher preparation, and institutional resistance to curricular innovation (König et al., 2020; Al-Kreimeen, 2024; Kebede et al., 2023).

A significant and internationally acknowledged research gap persists concerning the empirical evaluation of structured active-learning methodologies within TVET settings. While collaborative learning (CL), flipped learning, and competency-based models have demonstrated effectiveness in higher education, their systematic implementation, contextual adaptation, and rigorous assessment in vocational contexts remain underexplored (Johnson & Johnson, 2014; Rivera-Pérez et al., 2020). This gap represents not merely a literature deficit but a structural weakness undermining the capacity of TVET systems to align training processes with labor market transformations and pedagogical modernization imperatives.

The Chilean context exemplifies these global challenges with particular clarity. Technical higher education institutions in the country face pronounced curricular misalignments with contemporary industry requirements, compounded by resource scarcity, limited instructional innovation, and insufficient educator preparation and institutional support. Similar barriers are documented worldwide, reinforcing the need for research-informed policy and practice capable of closing these gaps (Madar et al., 2025; Masran et al., 2025).

Given the persistent underrepresentation of women in TVET and the documented gendered experiences shaping learning and professional development (Prieto-Saborit et al., 2021; Sarder et al., 2023), this study focuses exclusively on female students. It examines the effects of a structured, short-cycle collaborative learning intervention implemented in a technical-administrative program at a Chilean public university. The intervention targeted the five foundational CL dimensions—positive interdependence, promotive interaction, individual accountability, social skills, and group processing—using methodological frameworks and instruments adapted from internationally validated sources (Fernández-Río, 2017; Simesso et al., 2024).

This research addresses two central questions: (1) What measurable effects does a structured collaborative learning intervention have on collaborative competencies among female TVET students? and (2) How do these students perceive and evaluate their experiences with the implemented methodology?

Accordingly, the study pursues three specific aims: (a) to quantitatively assess the intervention's impact across five collaborative competency dimensions; (b) to qualitatively explore student perceptions, experiences, and evaluations, with emphasis on interpersonal and professional skill development; and (c) to examine the contextual relevance and transformative potential of structured collaborative learning for advancing pedagogical innovation, curricular alignment, and gender-responsive teaching in TVET.

By addressing these aims, the study seeks to provide empirical evidence contributing to global debates on pedagogical innovation and TVET modernization. Its findings offer actionable insights for educators, policymakers, and institutional leaders committed to building adaptive, equitable, and future-ready technical education systems. Furthermore, the study underscores the importance of replicable and context-sensitive research as a foundation for scalability and sustainability across diverse educational environments.

## 2. Theoretical Framework

### 2.1. Global Paradigms and Emerging Competencies in TVET

The transformation of TVET worldwide is inextricably linked to the accelerated digitalization of economic systems and the rise of Industry 4.0, which have radically redefined labor market demands and underscored the obsolescence of narrow, repetitive skillsets (Boltsi et al., 2024; Ciolacu et al., 2023; WEF, 2015). In response, education systems across Europe, Asia, and Latin America have increasingly adopted competency-based frameworks that emphasize not only technical expertise but also transversal competencies such as critical thinking, communication, teamwork, and adaptability (Mulder, 2017; Martinez, 2022). Policy initiatives such as Thailand 4.0, SkillsFuture in Singapore, dual VET models in Germany, and recent curricular reforms in Chile exemplify a global convergence toward embedding digital literacy, problem-solving, and innovation within TVET (Wicha et al., 2023).

Current research consistently demonstrates that employability now hinges on an integrated profile of technical, digital, and socio-emotional competencies—an imperative intensified by technological disruption and evolving industrial processes (Macanas & Rogayan, 2019; Hossain et al., 2019). Integrating computational thinking, STEM education, and multimodal learning into vocational curricula has become critical for bridging the gap between training and contemporary workplace needs. Recent empirical studies reinforce this claim: Roll and Ifenthaler (2021) found that “learning factories 4.0” can significantly enhance technical competence in vocational schools but have limited impact on transversal digital skills, revealing an enduring tension between specialized

technical training and holistic competence development. Similarly, Weijzen et al. (2023) argue that while collaborative, sustainability-oriented initiatives in vocational settings foster teamwork and problem-solving, most remain at the pilot stage and lack robust longitudinal evaluation. Collectively, this evidence positions TVET as a dynamic and adaptive educational sector that must continually evolve its pedagogical, curricular, and technological strategies to ensure both immediate employability and lifelong learning (Pratik et al., 2023; Masran et al., 2025). However, much of this work remains conceptual or institutionally bounded, highlighting the need for deeper empirical validation across diverse contexts.

## 2.2. Collaborative Learning and Active Methodologies in TVET

Within this context of pedagogical renewal, collaborative learning (CL) has gained prominence as an instructional paradigm capable of fostering cognitive, technical, and social development (Johnson & Johnson, 2014; Rivera-Pérez et al., 2020; Sutopo et al., 2020). Unlike unstructured group work, CL is defined by structured principles of positive interdependence, promotive interaction, individual accountability, social skills, and group processing (Gillies, 2016; Fernández-Río, 2017; López & Taveras, 2022; Paredes-Velasco et al., 2023), underpinned by sociocultural constructivism, social interdependence theory, and self-determination theory (Tadesse et al., 2024; Barceló-Cerdá et al., 2024; Pérez-Muñoz et al., 2022).

Extensive meta-analytic and empirical research confirms that CL enhances academic achievement, motivation, critical thinking, self-efficacy, and deep learning across multiple settings, including technical and vocational education (Rehman et al., 2024; Wu et al., 2024; Al-Kreimeen, 2024; Loza, 2024; Simesso et al., 2024; García-Taibo et al., 2024). Structured techniques such as Jigsaw, Jigsaw II, and the Student Team Achievement Division have proven effective in advancing collaborative problem-solving, conflict management, and participatory decision-making (Khataybeh et al., 2024; Barceló-Cerdá et al., 2024). International evidence also shows the adaptability of CL to multimodal and digital platforms, supporting blended and flipped learning models that reinforce both technical and communicative literacies (Pratik et al., 2023). Nevertheless, as Weijzen et al. (2023) highlight, many collaborative interventions in TVET remain confined to pilot initiatives and lack longitudinal validation or critical reflection on contextual transferability. This underscores an urgent need to consolidate evidence on how CL operates in practice-oriented environments, particularly regarding sustainability and gender inclusiveness.

The adoption of CL in TVET also faces persistent barriers such as limited instructional time, insufficient pedagogical training, and curricular rigidity (Al-Kreimeen, 2024; Kebede et al., 2023; García-Taibo et al., 2024). Recent scholarship further identifies conceptual tensions within CL itself, including high collinearity between social skills and group processing, indicating the need for contextual adaptation and theoretical refinement to align with the complex realities of technical education (Lorente et al., 2024a, 2024b).

## 2.3. Digitalization Multimodality, and Research Gaps in TVET Pedagogy

A defining feature of contemporary TVET is the pervasive influence of digitalization, which demands the integration of computational thinking, digital tools, and multimodal resources in both teaching and learning (Macanas & Rogayan, 2019; Rehman et al., 2024). The strategic use of simulation software, information and communication technology platforms, and technology-enhanced assessment strengthens technical and collaborative competencies, thereby improving employability, innovation, and adaptability outcomes (Pratik et al., 2023). International benchmarking illustrates the success of systems that combine digitalization with active, learner-centered approaches, as seen in reforms in Germany, Singapore, Thailand, Malaysia, and Australia (Wicha et al., 2023; Masran et al., 2025; Saeed et al., 2017; Power & Sorby, 2020). Yet empirical findings remain mixed: Roll and Ifenthaler (2021) observed that learning factories effectively enhanced domain-specific skills but failed to consistently foster cross-disciplinary digital competencies, highlighting the need for more pedagogically integrated models of digital learning.

Despite increasing attention, a persistent gap remains in the rigorous, context-sensitive study of structured collaborative and digital learning interventions in TVET—particularly in Latin America and other emerging economies (Schmid & Garrels, 2022; Sarder et al., 2023). The intersection of collaborative, technical, and digital competencies, along with the adaptation of evidence-based pedagogies to resource-constrained environments, continues to be underexplored (Mulder, 2017; Ciolacu et al., 2023; König et al., 2020). Moreover, gender-responsive perspectives remain largely absent from this body of research, despite growing evidence that women's participation and persistence in TVET are shaped by distinct motivational and institutional dynamics (Sevilla et al., 2023; Gutfleisch & Nennstiel, 2025). Addressing these research gaps is critical to ensuring that TVET fulfills its potential as a driver of inclusive economic development and social transformation in the era of the Fourth Industrial Revolution.

In response to these gaps, the present study examines the effects of a structured collaborative learning intervention implemented with female students in a Chilean TVET program. Using a quasi-experimental, mixed-

methods design, it assesses both quantitative and qualitative outcomes to better understand how collaborative learning fosters social, academic, and professional skill development in practice-oriented technical education.

### 3. Methodology

#### 3.1. Research Design

This study employed a quasi-experimental pretest–posttest design with a non-equivalent control group and a mixed-methods approach with quantitative emphasis. The primary aim was to evaluate the effects of a brief, structured CL intervention among TVET students. The quasi-experimental design was chosen due to ethical and logistical constraints that precluded full randomization, justifying the use of purposive and convenience sampling. The inclusion of qualitative analysis enriched the interpretation of observed effects and enhanced the contextual relevance of the findings. Importantly, the approach integrated statistical methods of both frequentist and Bayesian traditions, reflecting current recommendations for robust educational research.

The intervention consisted of four consecutive 90-minute sessions conducted once per week. This short-cycle format was determined by institutional scheduling constraints.

The sessions were facilitated by the course instructor, who followed a standardized collaborative learning protocol. The instructor provided brief task introductions, monitored adherence to group processes, and offered formative feedback while minimizing direct instruction. This procedure ensured implementation fidelity and maintained the learner-centered nature of the intervention.

#### Participants

The sample comprised 37 female students enrolled in the same curricular unit of a technical-administrative program at a regional public university in Chile, distributed across two campuses. Participants were selected through purposive convenience sampling, as all belonged to the only course section available during the intervention period. The group included students aged 18 to 55 years ( $M = 27.3$ ), approximately 40% of whom were first-generation higher education students and 80% reported concurrent employment. Sixteen students constituted the experimental group and 21 formed the control group; all participants were exposed to equivalent academic conditions. Group equivalence was established through Mann–Whitney U and chi-square tests on sociodemographic and academic variables, confirming no significant baseline differences. No attrition was recorded during the intervention.

#### 3.2. Instruments and Validation

Quantitative data were collected using a locally adapted version of the Cooperative Learning Questionnaire (CLQ; Fernández-Río et al., 2017), comprising 20 Likert-type items (1–5) spanning five dimensions: positive interdependence, promotive interaction, individual accountability, social skills, and group processing. Content validity was ensured through expert review; internal consistency (Cronbach's  $\alpha > .70$ ) was robust across dimensions. Exploratory and confirmatory factor analyses confirmed the instrument's structure (CFI = .93, TLI = .91, RMSEA = .059, SRMR = .062). An additional sociodemographic survey was administered.

For the qualitative component, a digital open-ended survey with nine questions captured students' perceptions of the intervention, skill development, challenges, and pedagogical improvement proposals.

#### 3.3. Ethical Considerations

All procedures strictly adhered to the ethical principles of the Declaration of Helsinki (World Medical Association, 2013) and Chilean educational research standards. Students were fully informed about study objectives, voluntariness, and data confidentiality, and provided informed digital consent. The study did not require formal ethics committee approval under local guidelines but maintained full compliance with institutional and international ethical standards.

#### 3.4. Data Analysis

Quantitative data were analyzed using Jamovi and R, selected for their transparency and open-source accessibility. Cronbach's alpha was used to assess reliability. The Shapiro–Wilk test indicated non-normality, justifying non-parametric tests: Wilcoxon signed-rank for within-group (pre–post) comparisons and Mann–Whitney U for between-group contrasts. Effect sizes were computed via rank-biserial correlation and Cohen's  $d$ . Bayesian analysis complemented frequentist statistics to provide probabilistic interpretations of the results. Posttest Spearman correlations explored associations among CL dimensions.

Qualitative data were analyzed inductively using Atlas.ti, chosen for its suitability for educational qualitative research. Two researchers independently coded a subset of responses, achieving 85% inter-coder agreement; discrepancies were resolved by consensus. Data saturation was considered achieved once no new themes

emerged. Thematic analysis yielded five emergent categories, triangulating with quantitative findings to enhance transferability and depth.

### 3.5. Limitations and Research Transparency

Key methodological limitations include the non-randomized design, potential residual confounding, and limited sample size, which may affect generalizability beyond the specific TVET context. Measures were taken to mitigate these risks by verifying baseline equivalence and employing robust analytical methods. Given the small-scale, real-world nature of the intervention, findings should be interpreted as contextually significant rather than universally generalizable.

## 4. Results

### 4.1. Reliability and Validity of the Instrument

The psychometric evaluation of the adapted (Fernández-Río et al., 2017) confirmed its robust internal consistency and factorial structure within the TVET context. Cronbach's alpha and McDonald's omega coefficients consistently exceeded .91 across all subscales and reached .987 and .988, respectively, for the total scale (see Table 1), indicating excellent reliability for both dimension-level and overall measurement.

**Table 1** Internal reliability by dimension and total scale

Scale	Mean	SD	Cronbach's $\alpha$	McDonald's $\omega$
Dimension 1	4.07	1.15	0.949	0.950
Dimension 2	4.01	1.17	0.946	0.947
Dimension 3	4.00	1.10	0.914	0.920
Dimension 4	3.98	1.15	0.942	0.943
Dimension 5	4.01	1.14	0.945	0.945
Total Scale	4.02	1.12	0.987	0.988

An exploratory factor analysis (EFA), conducted on a combined sample of 74 observations, employed the MINRES extraction method with oblique (Oblimin) rotation. Sampling adequacy metrics were optimal (KMO = .936; Bartlett's test  $p < .001$ ), supporting the suitability of the dataset for factor analysis. The EFA revealed a five-factor solution that aligned closely with the theoretical model, with most items displaying factor loadings above .40 (see Table 2). Certain items (13, 16, 17) demonstrated particularly strong loadings ( $\lambda > .80$ ), while a few exhibited cross-loadings suggestive of possible semantic overlap.

**Table 2** Factor loadings matrix (oblimin rotation) and item uniqueness

Items	F.1	F.2	F.3	F.4	F.5	Uniqueness
P.1	0.545					0.14656
P.2			0.325			0.14472
P.3	0.379					0.11824
P.4			0.697			0.12788
P.5				0.482		0.07046
P.6				0.536		0.09659
P.7				0.313	0.487	0.14283
P.8			0.583			0.36411
P.9	0.381				0.453	0.08850
P.10		0.987				0.00558
P.11	0.465				0.397	0.08986
P.12	0.398				0.481	0.01153
P.13	0.800					0.16502
P.14	0.657					0.08951
P.15	0.389	0.561				0.13714

Items	F.1	F.2	F.3	F.4	F.5	Uniqueness
P.16	0.832					0.10081
P.17	0.919					0.12095
P.18	0.602			0.344		0.07006
P.19	0.708		0.338			0.07593
P.20	0.732					0.10743

Although the RMSEA (.125) and TLI (.897) did not fully meet conventional thresholds, these deviations likely reflect the limited sample size, which may affect model stability and fit indices. Taken together, the reliability and validity analyses provide substantial preliminary evidence for the internal coherence and construct validity of the CLQ when adapted for TVET populations.

As shown in Tables 1 and 2, the results demonstrate that the CLQ exhibited strong psychometric performance across all dimensions, with consistently high reliability and clear factorial coherence. The factor structure closely mirrored the theoretical model, confirming that collaborative learning can be measured with precision and conceptual consistency in TVET settings. These findings not only validate the instrument’s adaptation but also reinforce the multidimensional nature of collaborative learning, integrating both cognitive and socio-emotional constructs relevant to technical education.

### 4.2. Descriptive Analysis

Descriptive statistics for the five CL dimensions, disaggregated by group and time point, revealed clear post-intervention trends. As displayed in Table 3, the experimental group’s posttest means surpassed those of the control group across all dimensions. Additionally, posttest standard deviations were substantially lower in the experimental group, reflecting increased response homogeneity and suggesting a strong, positive effect of the intervention.

**Table 3** Descriptive statistics and shapiro-wilk normality test by group and time point

Dimension	Time	Group	Mean	SD	Shapiro-Wilk W	Shapiro-Wilk p
Social Skills	Posttest	Control	16.0	4.81	0.741	<.001
		Experimental	19.0	1.46	0.737	<.001
	Pretest	Control	15.6	4.82	0.770	<.001
		Experimental	14.9	5.24	0.847	0.012
Group Processing	Posttest	Control	15.5	4.73	0.790	<.001
		Experimental	18.5	2.10	0.715	<.001
	Pretest	Control	15.7	5.15	0.791	<.001
		Experimental	14.8	5.33	0.860	0.019
Positive Interdependence	Posttest	Control	15.9	4.65	0.751	<.001
		Experimental	18.6	1.79	0.753	<.001
	Pretest	Control	14.9	4.53	0.810	<.001
		Experimental	15.2	5.06	0.844	0.011
Promotive Interaction	Posttest	Control	15.4	4.78	0.792	<.001
		Experimental	18.8	1.38	0.809	0.004
	Pretest	Control	14.8	4.80	0.856	0.005
		Experimental	15.2	5.29	0.829	0.007
Individual Accountability	Posttest	Control	15.9	4.81	0.783	<.001
		Experimental	18.3	1.77	0.841	0.010
	Pretest	Control	15.1	5.09	0.838	0.003
		Experimental	15.3	5.12	0.803	0.003

Normality testing with the Shapiro–Wilk procedure (see Table 3) demonstrated significant deviations from normal distribution in 17 of 20 group-dimension-timepoint combinations ( $p < .05$ ). This non-normality was most pronounced in the experimental group posttest scores, with several dimensions exhibiting leptokurtic distributions and notably compressed variance. These distributional properties, together with the modest sample size, justified the adoption of non-parametric statistical procedures for all subsequent inferential analyses, thereby reinforcing the robustness of the results.

As indicated in Table 3, the descriptive trends show that the experimental group not only achieved higher mean scores but also displayed markedly lower variance, signaling greater consensus and consolidation of learning outcomes. This pattern suggests that the intervention promoted a shared understanding and internalization of collaborative practices among participants. The stability of posttest responses further reflects the alignment between instructional design and learner engagement, confirming the intervention’s capacity to structure and equalize learning gains across individuals

### 4.3. Pretest–Posttest Within-Group Comparisons

Within-group change was examined using the Wilcoxon signed-rank test (see Table 4). In the control group, no statistically significant differences were found between pretest and posttest scores across the five CL dimensions ( $p > .05$ ), except for an isolated finding in positive interdependence ( $p = .040$ ;  $r = -0.57$ ), which should be interpreted cautiously given the risk of Type I error in small samples and multiple testing contexts. These null findings reinforce the internal validity of the design, as they suggest an absence of external confounding influences.

**Table 4** Wilcoxon signed-rank test results for within-group pretest–posttest comparisons

Dimension	Group	Statistic	p	$\Delta$ Mean	SE	95% CI Lower	95% Upper	CI Effect Size
Social Skills	Control	37.0	0.340	-1.000	1.092	-4.00	1.500	-0.2952
	Experimental	7.00	0.005	-3.50	1.35	-8.50	-1.500	-0.867
Group Processing	Control	48.0	0.888	1.41e-5	1.088	-3.00	2.500	0.0549
	Experimental	7.50	0.015	-4.00	1.39	-9.50	-1.000	-0.808
Positive Interdependence	Control	33.0	0.040	-1.500	0.936	-2.50	-4.57e-5	-0.5686
	Experimental	11.50	0.019	-3.50	1.36	-8.50	-1.000	-0.747
Promotive Interaction	Control	48.0	0.179	-1.000	1.041	-3.00	1.000	-0.3725
	Experimental	12.00	0.012	-3.00	1.38	-8.00	-1.000	-0.771
Individual Accountability	Control	43.0	0.202	-1.278	1.072	-3.50	1.000	-0.3676
	Experimental	18.50	0.035	-2.50	1.39	-8.50	-6.24e-5	-0.648

Conversely, the experimental group displayed statistically significant pretest–posttest gains across all five dimensions (all  $p < .05$ ), with consistently higher posttest scores (see Table 4). Effect sizes, computed as rank-biserial correlations, ranged from  $-0.65$  to  $-0.87$ , indicating a substantial and generalizable impact of the CL intervention, particularly for social skills, group processing, and promotive interaction. The magnitude and consistency of these effects underscore the pedagogical value of structured CL in technical higher education.

As summarized in Table 4, the intervention generated consistent and large-magnitude improvements across all collaborative learning dimensions. The strongest gains in social skills and group processing confirm that students not only learned to collaborate but also developed the interpersonal and metacognitive competencies necessary to sustain effective teamwork. These findings substantiate the transformative potential of structured CL methodologies in fostering both cognitive and socio-emotional development within short-cycle technical programs

### 4.4. Between Group Comparisons in Pretest and Posttest

To rigorously assess both the baseline equivalence of the experimental and control groups, as well as the differential impact of the CL intervention, Mann–Whitney U tests were conducted for each dimension of the CLQ at both pretest and posttest (see Table 5).

**Table 5** Mann–Whitney U test results for between-group comparisons in pretest and posttest

Dimension	Timepoint	Statistic	p	Mean Difference	95% CI Lower	95% CI Upper	Effect Size
Social Skills	Pretest	154	0.665	2.81e-5	-2.00	3.00	0.08631
	Posttest	84.5	0.009	-2.000	-4.00	-5.38e-5	0.497
Group Processing	Pretest	155	0.687	5.23e-5	-2.00	4.00	0.08036
	Posttest	83.5	0.008	-2.000	-4.00	-4.07e-5	0.503
Positive Interdependence	Pretest	150	0.589	-1.000	-3.00	2.00	0.10714
	Posttest	107.5	0.059	-2.000	-4.00	1.02e-5	0.360
Promotive Interaction	Pretest	151	0.610	-1.000	-3.00	3.00	0.10119
	Posttest	75.0	0.004	-2.000	-4.00	-1.000	0.554
Individual Accountability	Pretest	167	0.988	-7.13e-5	-3.00	3.00	0.00595
	Posttest	116.5	0.110	-1.000	-4.00	5.28e-6	0.307

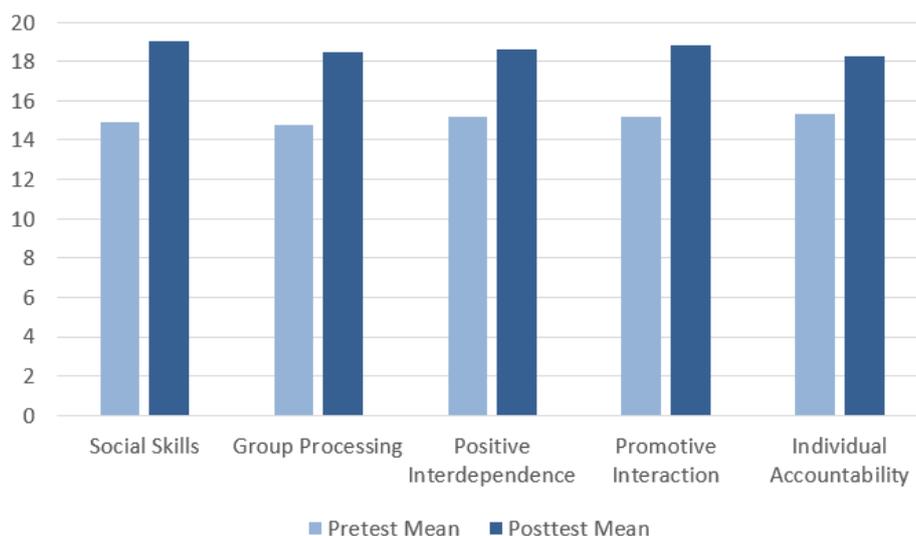
At baseline, the results confirmed that no statistically significant differences existed between the experimental and control groups across any of the five cooperative learning dimensions (all  $p > .58$ ; see Table 5). Mean differences were negligible, confidence intervals included zero throughout, and all effect sizes remained below 0.11. This statistical parity provides robust evidence that the two groups were initially comparable, thus reinforcing the internal validity of the quasi-experimental design and supporting causal inference regarding subsequent changes.

After the intervention, clear and statistically significant between-group differences emerged in three key CL dimensions: Social Skills ( $p = .009$ ,  $r = 0.497$ ), Group Processing ( $p = .008$ ,  $r = 0.503$ ), and Promotive Interaction ( $p = .004$ ,  $r = 0.554$ ), with all effect sizes falling within the moderate range (see Table 5). These findings highlight the pedagogical efficacy of the intervention in strengthening both interpersonal and metacognitive competencies in the experimental group.

Although the differences for Positive Interdependence ( $p = .059$ ,  $r = 0.360$ ) and Individual Accountability ( $p = .110$ ,  $r = 0.307$ ) did not reach conventional thresholds of statistical significance, the effect sizes for these dimensions suggest promising trends in favor of the experimental group. With larger samples or more intensive interventions, these effects may reach statistical significance.

Taken together, the data in Table 5 confirm that the intervention selectively enhanced those collaborative dimensions most dependent on group interaction and reflective dialogue. The emergence of moderate-to-strong effects in social skills, group processing, and promotive interaction indicates that the methodology effectively translated collaborative principles into observable behavioral and attitudinal change. The near-significant trends in interdependence and accountability further imply an underlying developmental process that may become more pronounced under extended implementation or broader curricular integration.

These patterns are visually summarized in Fig. 1, which provides a concise depiction of pre-post improvements across the five collaborative dimensions.



**Fig. 1** Pre-post mean scores across collaborative learning dimensions (experimental group)

As illustrated in Fig. 1, post-intervention improvements were evident across all collaborative learning dimensions, confirming the overall effectiveness of the structured CL intervention. The largest gains were observed in Social Skills (an average increase of 4.1 points) and Group Processing (an increase of 3.7 points), followed by Promotive Interaction (an increase of 3.6 points). These findings indicate that the intervention most strongly enhanced students' interpersonal, reflective, and participatory competencies—key attributes for teamwork and professional collaboration in technical fields. Moderate yet consistent improvements in Positive Interdependence (an increase of 3.4 points) and Individual Accountability (an increase of 3.0 points) suggest that participants also developed a greater sense of mutual responsibility and self-regulation within their teams. Collectively, these visual trends reinforce the statistical evidence presented in Table 5, underscoring the pedagogical value of structured collaborative learning in fostering both social and cognitive growth in TVET environments.

#### 4.5. Posttest Correlations Between Dimensions in the Experimental Group

To further illuminate the functional relationships among the five CL dimensions after the intervention, a Spearman correlation matrix was computed using posttest data from the experimental group ( $n = 16$ ; see Table 6).

**Table 6** Spearman correlations between cl dimensions at posttest (experimental group)

Dimensions	Social Skills	Group Processing	Positive Interdependence	Promotive Interaction	Individual Accountability
Social Skills	—	—	—	—	—
Group Processing	.915 ( $p < .001$ )	—	—	—	—
Positive Interdependence	.347 ( $p = .187$ )	.525 ( $p = .037$ )	—	—	—
Promotive Interaction	.763 ( $p < .001$ )	.882 ( $p < .001$ )	.674 ( $p = .004$ )	—	—
Individual Accountability	.370 ( $p = .159$ )	.368 ( $p = .161$ )	.482 ( $p = .059$ )	.488 ( $p = .055$ )	—

The results indicated several high-magnitude, statistically significant associations among the dimensions most directly related to interpersonal and group-level processes. Notably, Social Skills and Group Processing were extremely highly correlated ( $\rho = .915$ ,  $p < .001$ ), suggesting their mutual reinforcement during collaborative activities. Promotive Interaction also showed strong correlations with Group Processing ( $\rho = .882$ ,  $p < .001$ ), Social Skills ( $\rho = .763$ ,  $p < .001$ ), and Positive Interdependence ( $\rho = .674$ ,  $p = .004$ ). This constellation of relationships points to a cohesive, integrated functioning of these dimensions within the intervention context.

In contrast, Individual Accountability exhibited moderate but statistically non-significant correlations with other dimensions (all  $\rho \approx .48$ ,  $p > .05$ ). Although the small sample size may have limited statistical power, the moderate effect sizes suggest potentially meaningful functional links that merit further scrutiny in future research.

As revealed in Table 6, the high intercorrelations among social, interactive, and reflective dimensions confirm that collaborative learning operates as a synergistic construct rather than a set of isolated skills. The prominence of social skills and group processing as central nodes in this network underscores their foundational role in sustaining productive collaboration. Conversely, the weaker associations involving individual accountability suggest that self-regulatory aspects may develop more gradually, requiring explicit scaffolding in future instructional designs. These relational patterns provide further empirical support for the structural integrity of the CL model and its theoretical assumptions within technical education contexts.

#### 4.6. Qualitative Analysis of Student Perceptions

To enrich the quantitative findings and provide interpretive depth, a focused inductive thematic analysis was performed on 16 complete post-intervention responses. The coding process, conducted independently by two researchers with high inter-rater reliability (87.5%), produced a refined set of thematic categories, summarized in Table 7.

Anchored in a hermeneutic-constructivist paradigm, the analysis privileges the situated perspectives of learners as legitimate data for advancing pedagogical understanding, consistent with recent international calls for student-centered research in TVET (Mustaffa et al., 2023; Inchan & Akatimagool, 2025). The emergent categories reflect consensus on the value of CL for both conceptual and transversal skill development, with students highlighting increased communication, empathy, active participation, and professional competencies.

Participants highlighted strengthened communication, empathy, and collaboration throughout the intervention. As one student reflected, “We worked with respect, accepting our differences” (ID9), while another emphasized personal growth through challenge, noting that “Discomfort is the next step toward growth” (ID6). Others described increased confidence in teamwork and leadership, stating, “I strengthened my ability to communicate and work in a team” (ID12). These statements exemplify the socio-emotional and professional development achieved through collaborative learning and provide context for the thematic categories summarized below.

Table 7 presents a condensed analytical matrix that organizes the main emergent categories along with representative illustrative quotes:

**Table 7 Correspondence between theoretical dimensions and emergent categories**

Theoretical Dimension Inferred from the Model	Emergent Category Constructed from the Data	Illustrative Quote (ID)
Valuing the Collaborative Methodology	Enriching and Positive Experience	“Very rewarding and with excellent teachers” (ID 5)
Socio-emotional Learning Climate	Respect and Mutual Understanding	“We worked with respect, accepting our differences” (ID 9)
Active Participation and Meaningful Learning	Situated and Applied Learning	“It encouraged my active participation by applying what I learned” (ID 8)
Development of Interpersonal Skills	Communication, Empathy, Leadership, Listening	“I strengthened my ability to communicate and work in a team” (ID 12)
Development of Professional Skills	Applied Techniques and Problem-Solving	“I developed both technical and soft skills” (ID 2)
Conceptual Understanding Through Practice	Learning by Doing and Peer Teaching	“By carrying out what we learned, you realize you’ve truly learned” (ID 13)
Obstacles in Group Dynamics	Coordination Issues, Unequal Task Distribution	“Some worked more than others and some did nothing” (ID 10)
Constructive Reframing of Conflict	Growth Through Discomfort	“Discomfort is the next step toward growth” (ID 6)
Suggestions for Improvement	Extension to Other Courses, Self-Selection of Groups	“It should be used in all subjects” (ID 11); “Let us choose our own groups” (ID 10)

Notably, challenges inherent to collaborative work, coordination issues, uneven participation, were reframed by most students as developmental opportunities rather than obstacles, illustrating a mature grasp of the complexities of group dynamics in real-world educational settings. Suggestions for improvement, such as broader curricular integration and self-selection of groups, align with international best practices for scaling up collaborative pedagogies in diverse contexts.

As illustrated in Fig. 2, the most frequently reported themes were Enriching and Positive Experience and Respect and Mutual Understanding, each highlighted by over half of the participants. These categories capture the affective and relational essence of collaborative learning, underscoring how the structured intervention promoted empathy, communication, and a supportive learning climate. Situated and Applied Learning and Development of Interpersonal Skills also ranked highly, reflecting participants’ perception of collaboration as a bridge between classroom engagement and professional competence.

Less frequent yet pedagogically significant categories, Coordination Issues and Unequal Task Distribution and Growth Through Discomfort, illustrate that students interpreted conflict and imbalance not as failure but as opportunities for growth and self-regulation. Collectively, these patterns confirm that collaborative learning fostered both socio-emotional development and professional readiness, resonating with the quantitative improvements observed in interpersonal and metacognitive dimensions



**Fig. 2** Distribution of emergent categories from thematic analysis of student perceptions

As shown in Table 7 and illustrated in Fig. 2, the qualitative data reveal a coherent pattern of socio-emotional growth, cognitive engagement, and professional awareness among participants. Students’ reflections illustrate how structured collaboration promoted empathy, communication, and shared responsibility—skills directly aligned with the dimensions that improved most in quantitative analyses. This convergence underscores the transformative value of collaborative learning as both a pedagogical and developmental process, validating its relevance for TVET contexts seeking to balance technical proficiency with human-centered competencies.

#### 4.7. Triangulation of Findings

Mixed-methods triangulation enabled a rigorous synthesis between quantitative metrics and qualitative accounts, as outlined in Table 8. This process allowed for an interpretive dialogue across data strands, enhancing analytical robustness and international comparability.

**Table 8** Integration of quantitative and qualitative findings by analytical dimension

Quantitative Dimension	Key Quantitative Finding (Posttest)	Emergent Qualitative Correlate	Triangulated Interpretation
Social Skills	Significant increase in experimental group ( $p = .009$ ; $r = .50$ )	Strengthening of communication, empathy, active listening	Clear convergence: both approaches indicate improvement in key interpersonal competencies.
Group Processing	Significant improvement in experimental group ( $p = .008$ ; $r = .50$ )	Coordination, collaboration, reflection on group dynamics	Complementarity: qualitative analysis explains mechanisms underlying the observed gains.
Promotive Interaction	Higher scores in experimental group ( $p = .004$ ; $r = .55$ )	Active participation, peer teaching, respectful climate	Robust confirmation: evidence of deep learning processes mediated by dialogue.
Positive Interdependence	Non-significant favorable trend ( $p = .059$ ; $r = .36$ )	Role recognition, mutual support, joint work	Expansion: student narratives suggest latent processes not fully captured by the scale.
Individual Accountability	Non-significant differences ( $p = .110$ ; $r = .31$ )	Perceptions of individual commitment, unequal participation	Partial dissonance: while subjective perceptions indicate commitment, data show low posttest variability.

There was strong convergence between both data types for the core dimensions of Social Skills, Group Processing, and Promotive Interaction, all showing significant quantitative gains supported by rich qualitative

evidence of improvement in communication, coordination, and participatory learning. These findings echo global research documenting the impact of structured collaborative interventions in technical education settings (Barceló-Cerdá et al., 2024; Mafarja et al., 2025).

Positive Interdependence emerged as an area where qualitative insights extended the reach of quantitative measurement, revealing underlying collaborative processes and mutual support not fully captured by the standardized scale. Conversely, Individual Accountability highlighted a potential disconnect: while students reported high subjective commitment, objective scores remained statistically unchanged, raising important questions for future instrument refinement and deeper analysis of culturally mediated accountability norms in TVET.

In summary, the triangulated analysis not only confirms the effectiveness of the intervention but also illuminates key areas, such as interdependence and accountability, where measurement sensitivity and contextual adaptation are critical. The results underscore the need for ongoing methodological innovation and international dialogue in the study of CL within TVET.

## 5. Discussion

This study advances the evidence base on CL in short-cycle TVET, responding to both international recommendations (WEF, 2015; Schmid & Garrels, 2022) and regional needs for innovation and equity (Sarder et al., 2023; García-Taibo et al., 2024). By integrating quantitative and qualitative data, the study provides a multidimensional analysis of CL's impacts, encompassing cognitive, affective, and professional domains, and enhancing the ecological validity and interpretive depth of the findings.

### 5.1. Integration and Interpretation of Findings

Quantitative results showed statistically significant improvements in three of five CL dimensions, with moderate to large effect sizes and outstanding internal consistency ( $\alpha = .987$ ;  $\omega = .988$ ). These findings echo prior work demonstrating the effects of CL on self-regulation, intrinsic motivation, engagement, and critical thinking in higher and technical education (Lorente et al., 2024a, 2024b; Loza, 2024; Wu, 2025; Tinungki et al., 2024). The dimension of individual accountability, despite showing limited change, aligns with findings from other technical and physical education contexts (López & Taveras, 2022; Tamargo & Rodríguez, 2015), where it often emerges as a critical but challenging aspect to strengthen.

Factor analytic evidence supported the five-dimension model of the adapted CLQ (Fernández-Río et al., 2017), yet suboptimal fit indices (RMSEA = .125; TLI = .897) and observed cross-loadings reflect ongoing international debates about dimensional overlap, particularly among social skills, promotive interaction, and group processing (Delgado-García et al., 2021; Lorente et al., 2024b). The observed strong posttest correlations among these competencies suggest a more integrated, less hierarchical functioning in TVET contexts (Barceló-Cerdá et al., 2024), calling for refined theoretical models and locally validated instruments.

Qualitative findings reinforced and expanded on these results. Students described the intervention as pedagogically meaningful, reporting gains in teamwork, empathy, active listening, leadership, and conflict management, findings that resonate with research highlighting CL's value for social-emotional learning and emotional intelligence (Pérez-Muñoz et al., 2022; Rivera-Pérez et al., 2020; Rehman et al., 2024). The importance of a respectful and inclusive climate as a catalyst for engagement and deeper learning echoes conclusions from Matzumura-Kasano and Gutiérrez-Crespo (2021) and Simesso et al. (2024). Enhanced conceptual understanding through peer interaction, as described by participants, is consistent with evidence across teacher education (Hsu et al., 2025), chemistry (Simesso et al., 2024), and statistics (Tinungki et al., 2024), reinforcing the role of collaborative dialogue in facilitating critical engagement with content.

Nevertheless, persistent challenges were identified, such as uneven task distribution and coordination difficulties, long recognized as barriers to CL implementation (Lorente et al., 2024b; Nokes-Malach et al., 2015; Tamargo & Rodríguez, 2015). Rather than viewing these issues as failures, the literature and student voices suggest they should be approached as developmental opportunities, emphasizing the value of explicit instruction in collaborative norms, distributed leadership, and formative peer feedback (López & Taveras, 2022; Barceló-Cerdá et al., 2024; WEF, 2015).

### 5.2. Challenges, Contextual Factors, and Critical Reflections

The strengths of this study must be weighed against its limitations. The all-female, single-cohort sample and brief intervention period constrain generalizability and limit the observation of long-term effects (Prieto-Saborit et al., 2021; Pérez-Muñoz et al., 2022). Exclusive reliance on the CLQ instrument further restricts the psychometric depth of the analysis, while the absence of mediating variables such as motivation, self-efficacy, or digital mediation, recognized as relevant in contemporary CL research (Loza, 2024; Hsu et al., 2025; Hernández-Sellés et al., 2024; Parua & Yang, 2024), limits interpretive scope. Institutional and contextual factors, including curricular

rigidity and faculty training gaps, may affect transferability and sustainability of CL innovations in TVET (García-Taibo et al., 2024; Barceló-Cerdá et al., 2024).

It is also necessary to critically acknowledge that high intervention fidelity and student motivation in this pilot may not easily scale to broader, more heterogeneous settings, as cautioned in multi-institutional studies (Schmid & Garrels, 2022; Sarder et al., 2023). Additionally, the literature points to the importance of digital resources and blended methodologies for fostering autonomy and active participation in technical fields (Pratik et al., 2023; Ciolacu et al., 2023).

### 5.3. Implications for Policy and Practice

Empirical evidence from this and other recent studies (Madar et al., 2025; Masran et al., 2025; Mustaffa et al., 2023) highlights the potential of CL and allied methodologies, such as flipped learning and competency-based training (Mulder, 2017), to address persistent challenges in TVET, including dropout, skills mismatches, and the need for transversal competencies. However, sustainable adoption requires investment in faculty development, flexible curricula, validated assessment tools, and systemic support for curricular innovation (WEF, 2015; UNESCO, 2022).

Moreover, international experience underscores the need to position TVET at the forefront of educational and social policy agendas, given its strategic relevance for equity, national development, and workforce transformation (Schmid & Garrels, 2022; Sarder et al., 2023; Ciolacu et al., 2023). Integrating collaborative and active pedagogies, when contextually adapted and supported by institutional commitment, has the potential to transform not only academic achievement, but also professional and civic competence.

### 5.4. Synthesis and Future Directions

In conclusion, this study offers preliminary but robust evidence for the value and complexity of structured CL in technical higher education. It confirms the need for context-sensitive, theoretically rigorous, and empirically validated approaches to teaching and learning in TVET. Future research should pursue larger, more diverse samples, longitudinal and multivariate designs, and the integration of digital, intersectional, and labor market perspectives. Only through such an integrated, critical, and evidence-based approach can the field move towards more effective, equitable, and relevant educational experiences for technical and vocational students.

## 6. Conclusions

This study provides robust empirical evidence of the effectiveness of a structured collaborative learning (CL) intervention within short-cycle TVET in Chile, a sector often overlooked in mainstream educational research (Johnson & Johnson, 2014; Fernández-Río et al., 2017). In line with the study's objectives, the results demonstrated clear quantitative, qualitative, and contextual contributions: measurable improvement in collaborative competencies, meaningful student experiences, and evidence of feasibility in gender-specific, resource-constrained environments. The quantitative analyses demonstrated substantial and statistically significant improvements across the five dimensions of CL, particularly in social skills, group processing, and promotive interaction. These consistent gains confirm that structured collaboration can strengthen both interpersonal and metacognitive competencies in technical education, validating the theoretical model's coherence and its applicability to practice-oriented learning contexts.

Complementing these results, the qualitative findings offered a rich perspective on how students experienced and interpreted the intervention. Participants consistently described the process as transformative and professionally meaningful, highlighting advances in communication, leadership, empathy, and conflict management, as well as a renewed sense of preparedness for collaborative work environments. Such reflections reveal not only behavioral change but also deeper shifts in learners' professional identities and socio-emotional development, aligning with international evidence on the integrative value of CL for fostering the transversal competencies demanded by Industry 4.0 (WEF, 2015; Ciolacu et al., 2023).

The study also provides valuable insight into the contextual relevance and feasibility of implementing CL within gender-specific, resource-constrained TVET programs. The successful engagement of all-female cohorts illustrates how collaborative pedagogies can promote inclusion, empowerment, and equity in traditionally underrepresented populations. This outcome underscores the transformative potential of CL for gender-responsive educational innovation and institutional modernization within Latin American technical education systems.

Beyond these contributions, the research delivers preliminary psychometric evidence supporting the reliability and validity of the CLQ in Latin American TVET contexts—addressing a significant methodological gap and enabling more rigorous, context-sensitive evaluation of active pedagogies worldwide (Fernández-Río et al., 2017). From a practical and policy perspective, the findings advocate for the systematic integration of collaborative approaches into TVET curricula through faculty development, curricular redesign, and continuous

monitoring. As noted by Schmid and Garrels (2022) and Sarder et al. (2023), prioritizing TVET as a strategic lever for social inclusion and workforce innovation is crucial to meet the demands of the Fourth Industrial Revolution.

Nevertheless, the study's scope is limited by its modest sample size, short intervention period, and focus on a single program with exclusively female participants. Future research should expand to more diverse and longitudinal designs, incorporate intersectional analyses, and explore the digital mediation of CL processes in hybrid and online environments. Such efforts would advance understanding of how collaborative learning can sustain both technical proficiency and human-centered competencies across diverse TVET contexts.

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## Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper

## Author Contribution

Both authors made substantial contributions to all stages of the study, including the conception and design, data collection, analysis, and interpretation of results. They were jointly responsible for drafting, revising, and finalizing the manuscript. Both authors approved the final version and agreed to be accountable for all aspects of the work.

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