

Cloud collaborative learning environments for developing foreign language communicative competence in cadets within blended formats of military education

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ARTICLE INFO

Article history

Received 11 July 2026

Revised 17 September 2026

Accepted 21 September 2026

Available Online 14 October 2026

Keywords

EFL context

English language learning and teaching

Face-to-face learning

Linguistic university students

Synchronous online learning

ABSTRACT

The research aim is to formalise and empirically verify a multivariate model of the influence of a CCLE on the increase in cadets' foreign-language communicative competence, operationalising structural-interactional indicators and assessing their predictive contribution to variation in results. The study used a quasi-experimental pretest-posttest design with psychometric validation, intervention modelling, quantitative operationalisation of collaborative interaction, and multivariate statistical analysis. The control group followed the same ESP syllabus through instructor-led face-to-face lessons and individual LMS-supported tasks, without structured cloud co-authoring, formal peer review, or AI-supported rehearsal. The experimental group demonstrated a statistically significant increase in the integral index of foreign-language communicative competence of 0.62 standard deviations, with an effect size of 0.78 and model explanatory power of 38% of the variance. Interaction Density was a significant predictor ($\beta=0.41$) and correlated with ICC gain ($r=0.53$), providing evidence consistent with the proposed mediation mechanism. The scientific novelty lies in formalising a multilevel pedagogical model linking digital interaction parameters to foreign-language communicative competence and in providing quasi-experimental regression parameterisation in a blended military format. Prospects for further research include a multicentre longitudinal design, structural equation modelling, and integration of cognitive-motivational and learning-analytics indicators.



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How to Cite: Romaniuk, V., Nanivska, L., Danchenko, I., Derbak, O., & Namachynska, H. (2026). Cloud collaborative learning environments for developing foreign language communicative competence in cadets within blended formats of military education. *English Language Teaching Educational Journal*, 9(2), 416-434. <https://doi.org/10.12928/eltej.v9i2.17052>

1. Introduction

The relevance of the research is determined by the long-standing strategic role of foreign-language competence in officer education and operational interoperability (Tulloch, 1897; McCormick, 1970; Muller, 1981). Contemporary military language education additionally operates within digitally

mediated, collaborative and increasingly AI-supported learning ecologies, making pedagogical design not technology exposure alone the central issue for effectiveness ([Rahmati et al., 2021](#); [Siegel et al., 2024](#); [Makarenko et al., 2024](#)). Accordingly, the study examines CCLE as a pedagogically structured environment for developing foreign-language communicative competence (FLCC) in blended military education.

Research gap. Contemporary research on TEL, ESP and mobile-assisted language learning in military education remains fragmented across technology adoption, learner perceptions and isolated skill outcomes. The literature provides limited multivariate evidence explaining how observable digital interaction processes are associated with integrated FLCC development, and interaction density or discourse complexity are rarely operationalised as process predictors. A second gap concerns pedagogical mechanism: studies often report that a platform or online course was effective without distinguishing negotiation of meaning, peer scaffolding, task repetition, feedback uptake and lexical recycling as theoretically different pathways. A third gap concerns military blended learning, where hierarchical role structures, security restrictions and limited contact time can alter the affordances normally assumed in civilian CALL/TELL research. Consequently, an empirically verified model is required that links SLA/TESOL mechanisms, measurable interaction traces and multidimensional language outcomes within the same quasi-experimental design.

Problem statement. The unresolved problem is not simply whether CCLE can improve cadets' FLCC, but which pedagogical properties of cloud-mediated collaboration are associated with improvement and under what institutional constraints. Without process-level operationalisation, higher post-test scores can be attributed ambiguously to additional practice time, platform novelty, teacher mediation, learner motivation or genuine interactional mechanisms. The study therefore treats Interaction Density and Interaction Complexity as theoretically interpretable process indicators and tests their contribution after controlling measured baseline covariates. At the same time, the quasi-experimental design requires cautious inference because unmeasured teacher, affective and institutional factors cannot be eliminated completely. This formulation positions CCLE as a testable language-pedagogical model rather than as a claim that a particular vendor stack independently causes competence growth.

From an SLA/TESOL perspective, CCLE was conceptualised as a pedagogical mediation system rather than a bundle of digital services. Sociocultural Theory explains Teams/Docs-mediated peer activity as scaffolded co-construction; the Interaction Hypothesis foregrounds negotiation of meaning, clarification and feedback; Task-Based Language Teaching (TBLT) connects these processes to goal-directed operational tasks; and CALL/TELL and ESP pedagogy support multimodal practice in profession-specific communicative events ([Elabdali, 2021](#); [Canals & Mor, 2023](#); [Kim & Namkung, 2024](#); [Shadiev & Wang, 2022](#)). In this logic, synchronous briefing increases pushed output and rapid interactional repair, whereas asynchronous discussion extends planning time and creates a persistent record for noticing, reflection and reformulation. Collaborative authoring externalises language choices and makes peer scaffolding observable, while rubric-guided feedback directs attention toward pragmatic appropriateness and discourse organisation. The architecture therefore combines complementary temporal affordances rather than assuming that one delivery mode is optimal for all language processes. Role-based access, auditable course orchestration and asynchronous channels in the Microsoft/Google stack are particularly compatible with hierarchical military settings because they preserve formal responsibility while expanding low-risk opportunities for distributed participation and feedback. Formal permissions also allow instructors to retain pedagogical authority while cadets assume bounded peer roles, reducing the tension between learner-centred collaboration and institutional hierarchy. The theoretical novelty therefore lies in parameterising the language-learning mechanism through interaction density and discourse complexity rather than treating technology use itself as the explanatory variable.

Research questions. What is the structure and validity of the operationalisation of FLCC in a military context? What standardised increase in competence does intervention in CCLE provide compared to the traditional format? Is Interaction Density a predictor of ICC increase after controlling for relevant covariates?

Research hypothesis. The intensity and structural complexity of collaborative interaction in CCLE are associated with greater FLCC gains. Interaction Density and Interaction Complexity may account for part of the association between CCLE participation and FLCC gain. After controlling for baseline level and digital literacy, these indicators are expected to retain predictive power.

The research aim is to formalise and empirically verify a multivariate model of the influence of a CCLE on the growth of cadets' foreign-language communication skills within a blended military format and to operationalise structural-interaction indicators and assess their predictive contribution to the variation in learning outcomes.

Research objectives:

1. To conduct standardised testing and analytical assessment of FLCC with psychometric verification of the reliability and construct validity of the instruments.
2. To implement a quasi-experimental intervention design with pretest–posttest measurement to assess intervention-associated differences in FLCC within a blended military education format.
3. To operationalise collaborative digital interaction through formalised indicators of discourse density and structural complexity to quantitatively parameterise learning activity.
4. To apply multifactorial variation-regression analysis to determine the predictive power of interaction indicators and the explanatory power of the model of FLCC growth.

1.1. Literature Review

The digital transformation of military education has necessitated a rethinking of models for developing FLCC in blended-learning environments. Growing operational integration in multinational settings requires technologically mediated, collaboration-oriented environments with sustained interaction and empirically demonstrated effectiveness. The literature review therefore examined empirical trends, SLA/TESOL mechanisms, methodological differences and conceptual gaps in technology-supported language training for cadets.

Recent syntheses of technology-supported language learning showed that digital environments produce stronger outcomes when technology is embedded in explicit pedagogical design rather than added as an isolated delivery channel (Rahmati et al., 2021; Tao & Gao, 2022; Shadiev & Wang, 2022; Shadiev & Yu, 2024). Technology-mediated TBLT further links digital affordances to meaningful language use, sequenced tasks, learner agency and feedback, thereby providing a direct SLA rationale for the CCLE intervention (Canals & Mor, 2023; Kim & Namkung, 2024; Boers & Faez, 2026). This evidence shifts the analytical focus from platform adoption to the interactional processes that platforms enable.

Collaborative writing and peer-feedback research similarly supports the assumption that co-construction can externalise language-related reasoning, trigger negotiation and increase attention to form (Elabdali, 2021; Vuogan & Li, 2023). Online peer feedback has been associated with cognitive, affective and revision gains, although interaction quality varies across groups and conflicts may constrain co-construction (Cao et al., 2022; Chen & Lee, 2022). Multimodal and digitally assessed collaborative writing studies further indicate that visible revision histories and process-oriented assessment can strengthen collaboration, fluency and complexity (Cheung, 2022; Zhang & Chen, 2022; Sang & Zou, 2023).

For oral communication, synchronous and AI-mediated practice can increase opportunities for rehearsal, turn-taking and willingness to communicate, but the pedagogical value depends on feedback quality and task authenticity (Engwall et al., 2022; Yang et al., 2022; Zhang et al., 2024). Fluency is also sensitive to affective and temporal conditions, whereas pragmatic development requires explicit attention to context-sensitive choices and speech acts (Aubrey, 2022; Huang, 2022; Omar & Razi, 2022). These findings support the present distinction between Fluency Rate and Pragmatic Adequacy rather than treating speaking performance as a unitary outcome.

Vocabulary development presents a complementary constraint. Technology-assisted vocabulary interventions are generally effective, yet durable lexical growth depends on repeated retrieval, contextual recycling and sustained exposure rather than interaction frequency alone (Yu & Trainin, 2022). AI-supported dialogue and scaffolding can expand rehearsal and idea generation, while systematic reviews also identify risks related to accuracy, privacy and over-reliance on generated output (Guo et al., 2022; Pack & Maloney, 2024; Yang & Li, 2024; Li et al., 2024; Lo et al., 2024; Deng et al., 2025; Chang & Sun, 2024). Therefore, AI was treated as a bounded rehearsal resource within CCLE, not as an autonomous instructional agent.

Military-language research confirms that interaction takes place under distinctive institutional constraints. Active listening, mobile vocabulary learning and English-for-military-purpose studies indicate the importance of professional relevance, structured participation and role-sensitive communication (Bjornestad et al., 2021; Hsu & Chao, 2023). Earlier work on military ICT, intercultural preparation and aviation-language task specification also supports authentic mission-oriented scenarios, while recent scoping evidence shows persistent heterogeneity in designs and outcome measures (Madej, 2017; Niculescu et al., 2019; Park, 2020; Rahman et al., 2023; Rochmawati et al., 2023; Siegel et al., 2024; Martin, 2021).

Across adjacent educational-technology research, cloud and AI-supported learning has been associated with improved access, self-direction and collaborative learning, but institutional implementation still requires transparent analytics, teacher orchestration and data governance (Li & Mak, 2022; Li et al., 2022; Lai et al., 2022; Kühl & Wohninsland, 2022; Kim et al., 2022; Khrapatyi et al., 2024; Casal & Kessler, 2024; Römer, 2024). The unresolved issue is therefore not whether digital tools can support language learning, but which interactional properties explain competence growth in a regulated blended environment. The present study addresses this gap by testing the CCLE–Interaction Density–ICC Gain model while retaining teacher mediation and profession-specific task design as pedagogical controls.

2. Methods and Materials

2.1. Research Procedure

The research design. The design used (Fig. 1) combined diagnostic validation, intervention exposure, post-test assessment, and multivariate modelling. This structurally sequential configuration supported internal validity, covariate control, and operationalisation of the proposed mechanism. Quasi-experimental comparison of control and experimental groups reduced systematic bias and supported adjusted inference about intervention-associated FLCC change without assuming definitive causality.

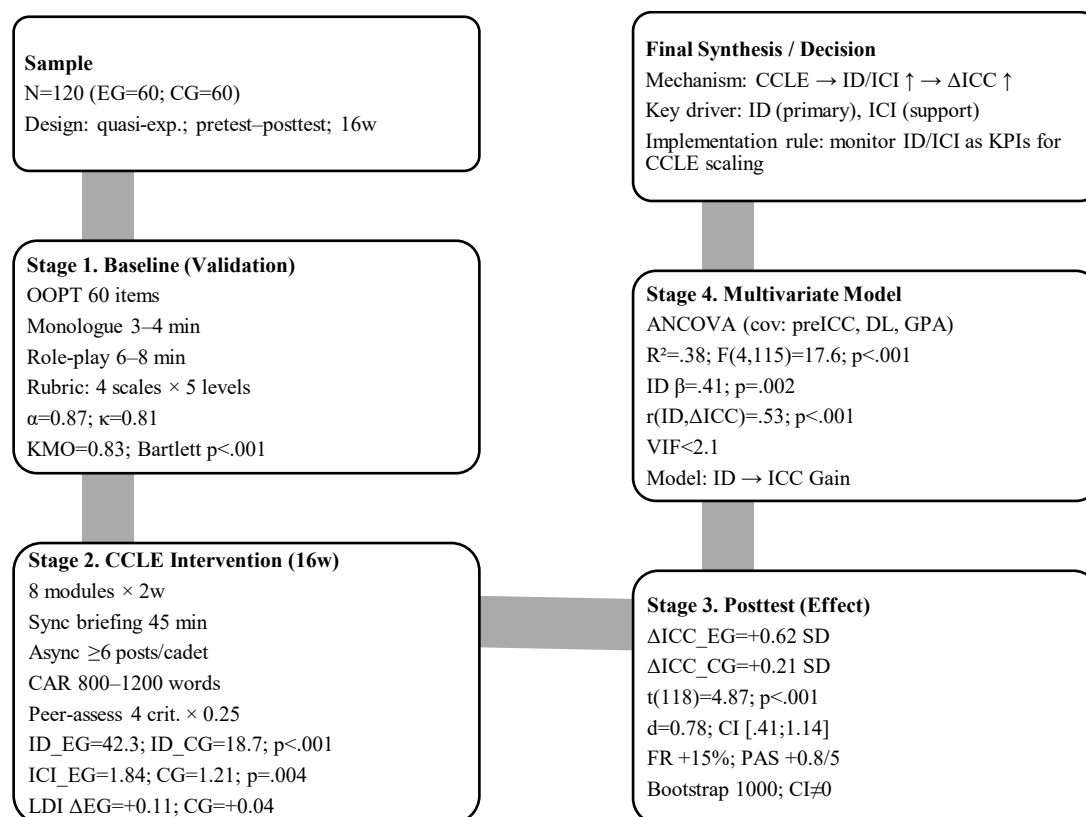


Fig 1. Structurally sequential quasi-experimental model of empirical verification of CCLE effectiveness in a blended military format

Source: developed by the authors

2.2. Methods

The study was based on a quasi-experimental paradigm combining psychometric validation, intervention modelling, and multivariate statistical analysis. This methodology integrated competence-based, activity-based, sociocognitive, and interactionist perspectives with quantitative verification of educational effects. The design enabled a transition from diagnostic description to adjusted multivariate interpretation of the association between CCLE participation and FLCC development. (1) *Standardised testing and analytical assessment*. A standardised language test was used in combination with an analytical rubric to assess oral discourse. This approach ensured the objectification of lexical-grammatical, pragmatic and structural parameters of speech. Psychometric testing of reliability and construct validity ensured the tool's internal consistency.

(2) Before formal scoring, two ESP/EFL raters completed a calibration session using 12 anonymised pilot recordings excluded from the analytical dataset. They jointly aligned descriptors and anchor examples for lexical variety, fluency, pragmatic adequacy and structural complexity, then independently rescored the calibration set and reconciled divergent interpretations. Formal double rating proceeded after descriptor stabilisation; the subsequent inter-rater agreement reached Cohen's $\kappa=0.81$. (3) FLCC was operationalised as a multidimensional performance construct. LDI indexed lexical-linguistic resources; FR represented processing fluency and strategic management of real-time speech; PAS captured sociolinguistic-pragmatic appropriateness; and ICI represented discourse organisation and interactional complexity. This mapping was selected because operational military communication requires simultaneous access to lexical resources, timely production, context-appropriate choices and coherent interaction rather than isolated grammatical knowledge. LDI and FR were derived from observable language production, whereas PAS and ICI captured functional adequacy and discourse organisation through the analytic rubric and coded features. The four indicators therefore triangulated product, processing and interactional dimensions of performance. They do not exhaust communicative competence, particularly receptive knowledge and broader intercultural competence, but together sample complementary linguistic, strategic, sociolinguistic and discourse dimensions. Their aggregation was retained only after reliability, inter-rater agreement and factor-structure checks supported the measurement model, which reduced the risk of interpreting a single fluency or vocabulary measure as equivalent to FLCC as a whole. This operationalisation was explicitly anchored in the pedagogically motivated communicative competence model of Celce-Murcia, Dörnyei, and Thurrell (1995), which distinguishes linguistic, discourse, sociocultural, strategic, and actional competencies. Within this framework, LDI primarily sampled linguistic competence, FR strategic real-time management, PAS sociocultural/actional appropriateness, and ICI discourse competence; the correspondence was treated as partial rather than one-to-one.

(4) *Quasi-experimental intervention design*. The intervention was organised as a controlled pretest–posttest comparison. Equivalent curricular targets and contact-time allocations were maintained across groups, while the experimental condition added structured cloud collaboration. This design strengthened internal validity but did not eliminate teacher, motivation, engagement, novelty, or institutional effects; therefore, results were interpreted as evidence of intervention-associated effectiveness rather than definitive causality. (5) *Quantitative parameterisation of collaborative interaction*. Digital interaction was operationalised through indicators of discourse density and structural complexity. This enabled a transition from a qualitative description of activity to its formalised measurement, making it possible to investigate not only the fact of technology use but also the intensity and cognitive depth of educational interaction. (7) *Multivariate statistical analysis*. Variational and regression procedures with covariate control were used to estimate adjusted associations and predictor contributions. This enabled assessment of the explanatory power and stability of the model while reducing confounding from measured baseline differences. Multivariate analysis therefore provided a structural, rather than deterministic causal, interpretation of FLCC growth within CCLE.

2.3. Sampling

The empirical study was conducted between 2 September and 20 December 2025 at military HEIs. The sample was formed using stratified quasi-randomisation at the level of educational units; $n=120$ cadets in the II–III courses ($EG=60$; $CG=60$), with an average age of 19.8 ± 0.7 years. The inclusion criteria were: English proficiency at B1–B1+ according to the CEFR, no academic debt, basic digital literacy (Digital Literacy Index ≥ 0.6), and regular participation in the educational process (attendance

$\geq 90\%$). Exclusion criteria were previous experience of long-term study abroad (>6 months) and participation in parallel language programmes.

An a priori power analysis for an ANCOVA/multiple-regression model with four predictors, an anticipated medium effect ($f^2=0.15$), $\alpha=0.05$ and statistical power of 0.80 indicated a minimum sample of 85 participants. The realised sample of $N=120$ therefore exceeded the minimum requirement and retained a margin for group allocation and possible attrition. The control group followed the same ESP syllabus and contact-time allocation through instructor-led face-to-face practice and individual Moodle-supported tasks, without structured cloud co-authoring, formal peer-review cycles, or AI-supported rehearsal.

Socio-demographic variables (gender, region of origin, socioeconomic status) did not show a statistically significant effect on the pretest ICC ($p > 0.05$), confirming the homogeneity of the sample. All participants provided written informed consent to participate and to the processing of personal data in accordance with the principles of the GDPR and national legislation; the data was depersonalised and coded with identifiers. The local ethics committee approved the study; the principles of voluntariness, confidentiality and non-discrimination were observed.

2.4. Research Tools

The use of the proposed mathematical tools was dictated by the need to formalise the operationalisation of the multidimensional construct of FLCC and to ensure the statistical verifiability of the hypothesis of CCLE's intervention effect. The use of standardisation, parametric criteria, ANCOVA modelling, and mediation analysis enabled the minimisation of confounding, the control of covariates, and the estimation of effect sizes in SD units. The integration of correlation, regression, and bootstrap approaches ensured the robustness of estimates, internal validity, and reproducibility of empirical results:

a) Indexation, sets, basic variables.

Let $i \in \{1, \dots, N\}$ denote a participant, $g \in \{EG, CG\}$ denote a group, $t \in \{0, 1\}$ denote the measurement time (pretest/posttest), $m \in \{1, \dots, 8\}$ denote a module, $r \in \{1, \dots, R\}$ denote an expert (rater). Observations were denoted as $X_{i,g,t}$, covariates as C_i (e.g., DL_i – digital literacy, GPA_i – academic performance, B_i – baseline language level). The binary intervention indicator was set to $Tg \in \{0, 1\}$, with $TEG=1$ and $T_{CG}=0$.

b) Operationalisation of ICC components.

- 1) Lexical density was defined as the proportion of content words in the transcript:

$$LDI_{i,t} = \frac{N_{i,t}^{content}}{N_{i,t}^{tokens}}. \quad (1)$$

- 2) Speech rate (fluency) was defined as the number of words per minute:

$$FR_{i,t} = \frac{N_{i,t}^{tokens}}{Time_{i,t}^{min}}. \quad (2)$$

- 3) Pragmatic adequacy was aggregated from the rubric (0–5) according to criteria $k \in \{1, \dots, K\}$ with predefined weights:

$$PAS_{i,t} = \sum_{k=1}^K w_k Score_{i,t,k}. \quad (3)$$

- 4) The interaction complexity index was calculated as the weighted sum of syntactic and discursive features (e.g., subordinate clauses and discourse markers):

$$ICI_{i,t} = \sum_{j=1}^J a_j Feature_{i,t,j}, \sum_j a_j = 1. \quad (4)$$

c) Standardisation and the ICC integrated indicator.

- 1) For comparability of metrics, z-normalisation was applied based on the pooled pretest distribution:

$$zX_{i,t} = \frac{X_{i,t} - \mu_{X,0}}{\sigma_{X,0}}, X \in \{LDI, FR, PAS, ICI\}. \quad (5)$$

- 2) The integral index was defined as the average of standardised components:

$$ICC_{i,t} = \frac{1}{4}(zLDI_{i,t} + zFR_{i,t} + zPAS_{i,t} + zICI_{i,t}). \quad (6)$$

- 3) The increase in competence was recorded as:

$$\Delta ICC_i = ICC_{i,1} - ICC_{i,0}. \quad (7)$$

- 4) The intervention effect hypothesis was formalised as:

$$H_1 : E[\Delta ICC|EG] - E[\Delta ICC|CG] \geq 0.4, \quad (8)$$

where 0.4 was interpreted in SD units.

d) *Interaction indicators in CCLE.*

- 1) Interaction density for a participant was defined as the number of content turns per period, normalised by the number of co-participants:

$$ID_i = \frac{\sum_{m=1}^8 MT_{i,m}}{N_i^{group}}, \quad (8)$$

where $MT_{i,m}$ – content turns in module m , and N_i^{group} – size of the collaboration group.

- 2) Group averages were calculated as:

$$\overline{ID}_g = \frac{1}{N_g} \sum_{i \in g} ID_i. \quad (9)$$

e) *Reliability, consistency, and validity of measurements.*

- 1) Internal consistency of the scale was assessed using Cronbach's alpha:

$$\alpha = \frac{K}{K-1} \left(1 - \frac{\sum_{k=1}^K \sigma_k^2}{\sigma_{total}^2} \right), \quad (10)$$

where K is the number of points/criteria.

- 2) Inter-expert agreement for categorical levels was determined using Cohen's kappa:

$$\kappa = \frac{p_0 - p_e}{1 - p_e}. \quad (11)$$

- 3) Construct validity was tested using a factor model:

$$x_i = \Lambda f_i + \varepsilon_i, \Sigma = \Lambda \Phi \Lambda^T + \Psi. \quad (12)$$

f) *Effect verification: t-test and effect size.*

- 1) The difference in gains between groups was tested using a t-test (Welch or pooled depending on the variances):

$$t = \frac{\overline{\Delta ICC}_{EG} - \overline{\Delta ICC}_{CG}}{\sqrt{\frac{s_{EG}^2}{N_{EG}} + \frac{s_{CG}^2}{N_{CG}}}}. \quad (13)$$

- 2) The size of Cohen's d was defined as:

$$d = \frac{\overline{\Delta ICC}_{EG} - \overline{\Delta ICC}_{CG}}{s_p}, s_p = \sqrt{\frac{(N_{EG} - 1)s_{EG}^2 + (N_{CG} - 1)s_{CG}^2}{N_{EG} + N_{CG} - 2}}. \quad (14)$$

The confidence interval (generalised) for d was set as $d \pm z_{0.975} \times SE(d)$.

g) *ANCOVA model (covariate control).*

- 1) Multivariate testing was performed using ANCOVA/GLM:

$$ICC_{i,1} = \beta_0 + \beta_1 T_g + \beta_2 ICC_{i,0} + \beta_3 DL_i + \beta_4 GPA_i + \varepsilon_i, \quad (15)$$

where β_1 was interpreted as the net effect of the intervention, controlling for baseline and covariates.

- 2) Explanatory power was estimated as:

$$R - \text{squared} R^2 = 1 - \frac{\sum_i (y_i - \hat{y}_i)^2}{\sum_i (y_i - \bar{y})^2}, \quad (16)$$

- 3) The homogeneity of regression slopes was tested through an interaction term:

$$ICC_{i,1} = \dots + \gamma(T_g \times ICC_{i,0}) + \varepsilon_i, H_0 : \gamma = 0. \quad (17)$$

h) *Correlation and mediation logic “ID → ICC Gain”.*

- 1) The relationship between interaction density and competence gain was assessed using Pearson correlation:

$$r = \frac{\sum_i (ID_i - \overline{ID})(\Delta ICC_i - \overline{\Delta ICC})}{\sqrt{\sum_i (ID_i - \overline{ID})^2 \sum_i (\Delta ICC_i - \overline{\Delta ICC})^2}}. \quad (18)$$

- 2) The mediating structure was specified by a regression system and evaluated with bootstrap confidence intervals:

$$\begin{aligned} \Delta ICC_i &= cT_g + u_i, \\ ID_i &= aT_g + v_i, \\ \Delta ICC_i &= c'/T_g + bID_i + e_i, \end{aligned} \quad (19)$$

where the indirect effect was estimated as ab , and its significance was assessed using a bootstrap CI.

i) *Assumption testing and robust validation.*

- 1) The normality of residuals was tested using Shapiro–Wilk:

$$H_0 : \text{normality}. \quad (20)$$

- 2) Homogeneity of variances was tested using Levene’s test:

$$H_0 : \sigma_{EG}^2 = \sigma_{CG}^2. \quad (21)$$

- 3) The stability of the estimates was assessed by bootstrap resampling:

$$\hat{\theta}^{(b)} (b = 1, \dots, B), CI_{0.95} = [Q_{0.025}, Q_{0.975}], \quad (22)$$

where $Q_p - p$ is the p -quantile of the empirical distribution $\hat{\theta}^{(b)}$.

j) *Data quality indicators.*

- 1) Dropouts/absences were coded as missingness indicators; participation level was retained as a data-quality variable, with attendance
- ≥ 0.90
- as the inclusion threshold:

- 2) Multicollinearity in GLM was controlled using variance inflation factors:

$$VIF_j = \frac{1}{1 - R_j^2}. \quad (23)$$

The developed toolkit enabled the formalised operationalisation of ICC, parameterisation of interaction in CCLE via ID, verification of the intervention effect hypothesis (t-test, d), and multivariate validation (ANCOVA, mediation, bootstrap) in a replicable pretest–posttest design.

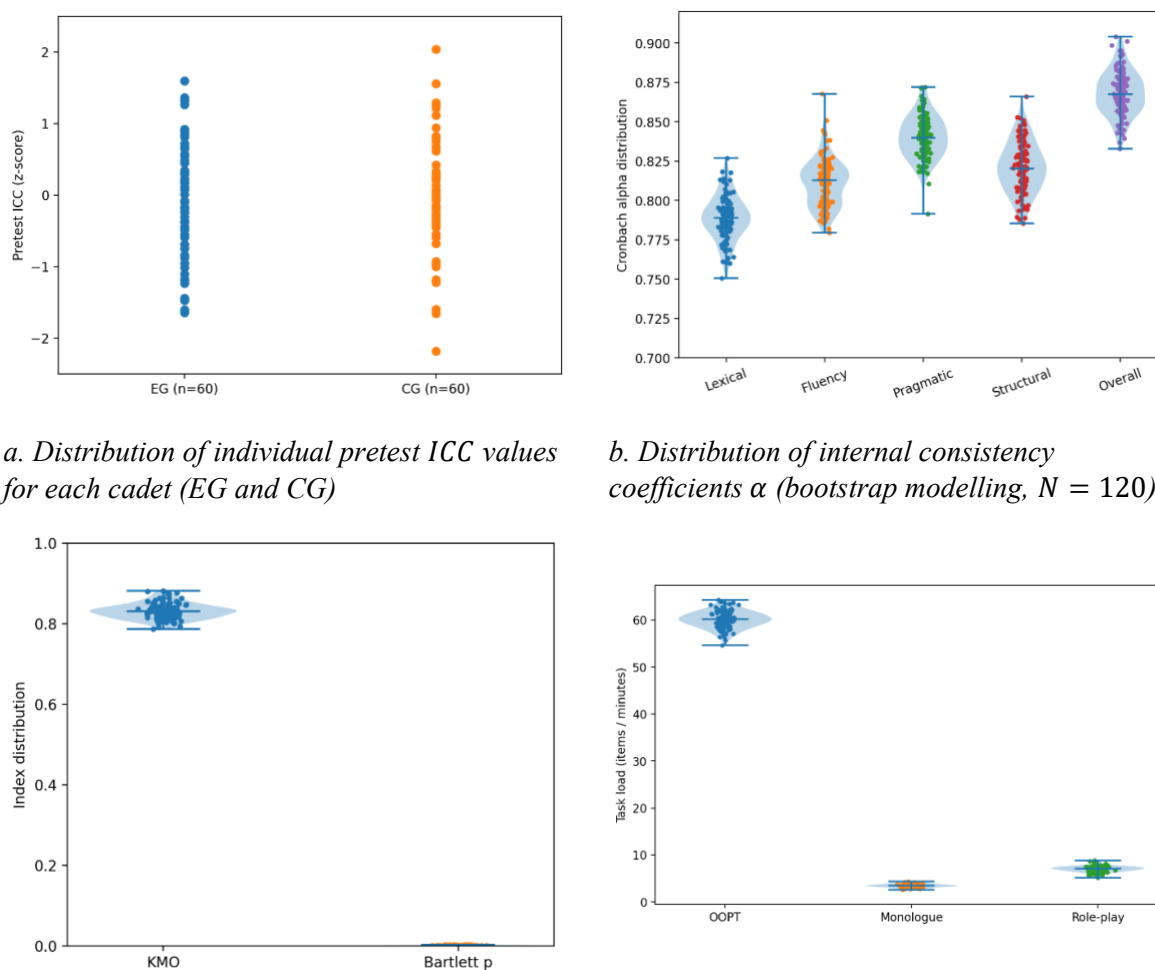
For statistical processing and modelling, Python was used with NumPy and Pandas for data handling, SciPy and statsmodels for inferential statistics and ANCOVA/GLM, scikit-learn for standardisation and

model validation, and Matplotlib for diagnostic visualisation. The open-source stack supported reproducible analysis, transparent assumption checking and bootstrap resampling while reducing licensing constraints.

3. Findings and Discussion

3.1. Result

The initial measurement was aimed at empirical calibration of the instrumentation and formation of a valid metric base for further intervention modelling (Fig. 2). A combined battery (OOPT – 60 items; monologue 3–4 min; role simulation 6–8 min) provided multi-component operationalisation of *ICC* through LDI, FR, PAS and ICI. The use of a 4×5 analytical rubric, assessment of internal consistency (α), inter-expert agreement (κ) and factor adequacy (*KMO*, Bartlett) made it possible to verify the psychometric stability of the measurement model before the implementation of CCLE.



a. Distribution of individual pretest ICC values for each cadet (EG and CG)

b. Distribution of internal consistency coefficients α (bootstrap modelling, $N = 120$)

c. Distribution of construct validity indicators: *KMO* and Bartlett's p -value test

d. Distribution of diagnostic battery parameters (OOPT, Monologue, Role-play)

Fig 2. Basic diagnostic validation of the instrumentation and distribution of individual indicators of FLCC scores among cadets ($N = 120$)

Source: developed by the authors

The distribution of individual pretest *ICC* (Fig. 2, a) demonstrated the metric symmetry of EG and CG and the absence of significant initial differences ($p > 0.05$). Reliability indicators ($\alpha = 0.87$, $\kappa = 0.81$) confirmed the internal consistency of the scales (Fig. 2, b), and $KMO=0.83$, $p < 0.001$ (Fig. 2, c) confirmed the adequacy of the latent structure of the four factors. The structural balance of the diagnostic components (Fig. 2, d) confirmed the representativeness of the measurements. It provided a correct basis for calculating ΔICC in further analysis.

The proposed CCLE architecture (Fig. 3) was designed according to the principle of vertical modular stratification (Access → Orchestration → Collaboration → Content → Assessment → AI → Analytics), which ensured functional decomposition, scalability, and controlled telemetry of learning interactions. The integration of cloud services across different operational specialisations minimised coordination transaction costs. It ensured the traceability of *ID*, *ICI*, and ΔLDI indicators in real time. This configuration met the requirements of a blended military education format, given limited classroom resources and highly regulated processes.

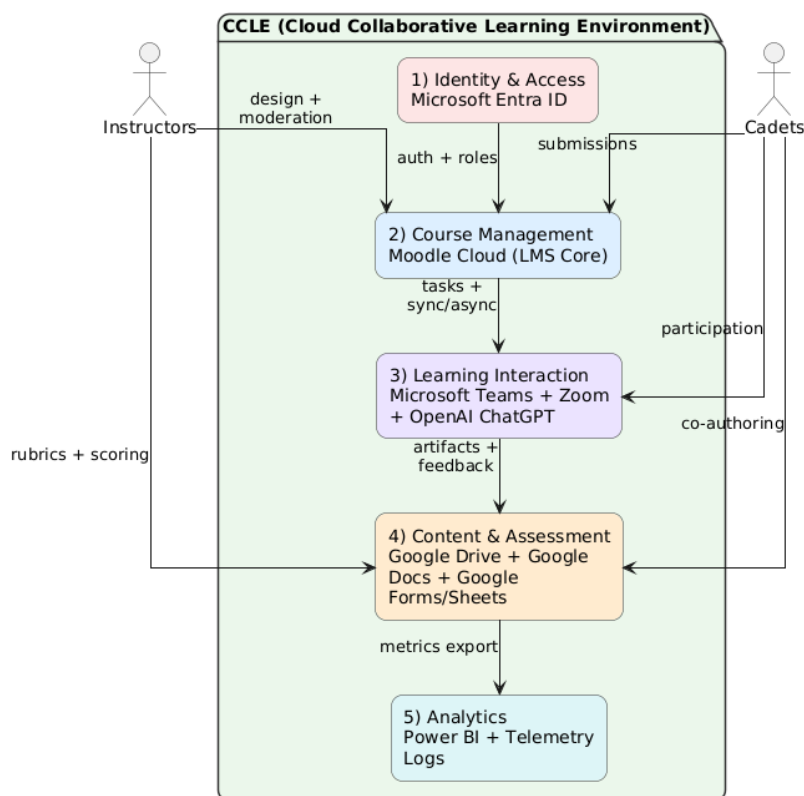


Fig 3. Modular multi-level architecture of a CCLE for developing cadets' foreign language communication skills

Source: developed by the authors

The developed CCLE architecture (Fig. 3) integrated Microsoft Entra ID for identity and role control, Moodle Cloud for course orchestration, Microsoft Teams and Zoom for synchronous/asynchronous interaction, Google Drive/Docs for collaborative documentation, Google Forms/Sheets and Moodle Workshop for rubric-based assessment, OpenAI ChatGPT for bounded rehearsal, Power BI for learning analytics, and Microsoft Purview/DLP for audit and data protection. The services were treated as interchangeable functional layers rather than mandatory vendor dependencies, allowing the pedagogical model to be migrated to institutionally approved or on-premise equivalents.

The 16-week course comprised eight two-week task cycles. Each cycle combined pre-task listening and terminology priming, a time-bounded operational briefing or information-gap role-play, an asynchronous situation-report/problem-solving discussion with at least six substantive contributions per cadet, collaborative production of an 800–1200-word after-action report, and rubric-based peer review. The task sequence moved from supported input to increasingly autonomous output: cadets first extracted mission-relevant information, then negotiated a response, produced an oral briefing, documented the decision collaboratively and revised the product after feedback. Speaking was developed through briefings, clarification, confirmation checks and negotiated decision-making; listening through mission audio, peer briefings and information-gap completion; vocabulary through scenario-based recycling, shared glossaries and collaborative documentation; and pragmatic competence through rank-sensitive requests, mitigation, repair and clarification.

Small-group interaction was prioritised for information-gap and decision tasks because it increased individual turn opportunities while preserving peer support, whereas plenary briefings were retained for accountability and professional register. Instructors acted as task designers, moderators and feedback

providers, using recasts for low-disruption correction, elicitation for self-repair, metalinguistic prompts for recurrent errors and rubric comments for delayed reflection. Feedback was delivered during or immediately after task cycles and was linked to the same four performance dimensions used in assessment. AI support was restricted to rehearsal, alternative phrasing and formative feedback rather than final assessment; generated language was checked against course materials and instructor guidance before reuse.

The standardised baseline ICC indicator enabled subsequent gains to be expressed in SD units and allowed pretest performance, digital literacy and academic achievement to be controlled in the multivariate model. The 16-week CCLE configuration was therefore analysed through complementary process indicators (ID and ICI) and outcome indicators (LDI, FR, PAS and integral ICC). This psychometrically validated structure supported progression from descriptive comparison to adjusted inferential testing of whether collaborative-intensity differences were associated with competence gains (Fig. 4).

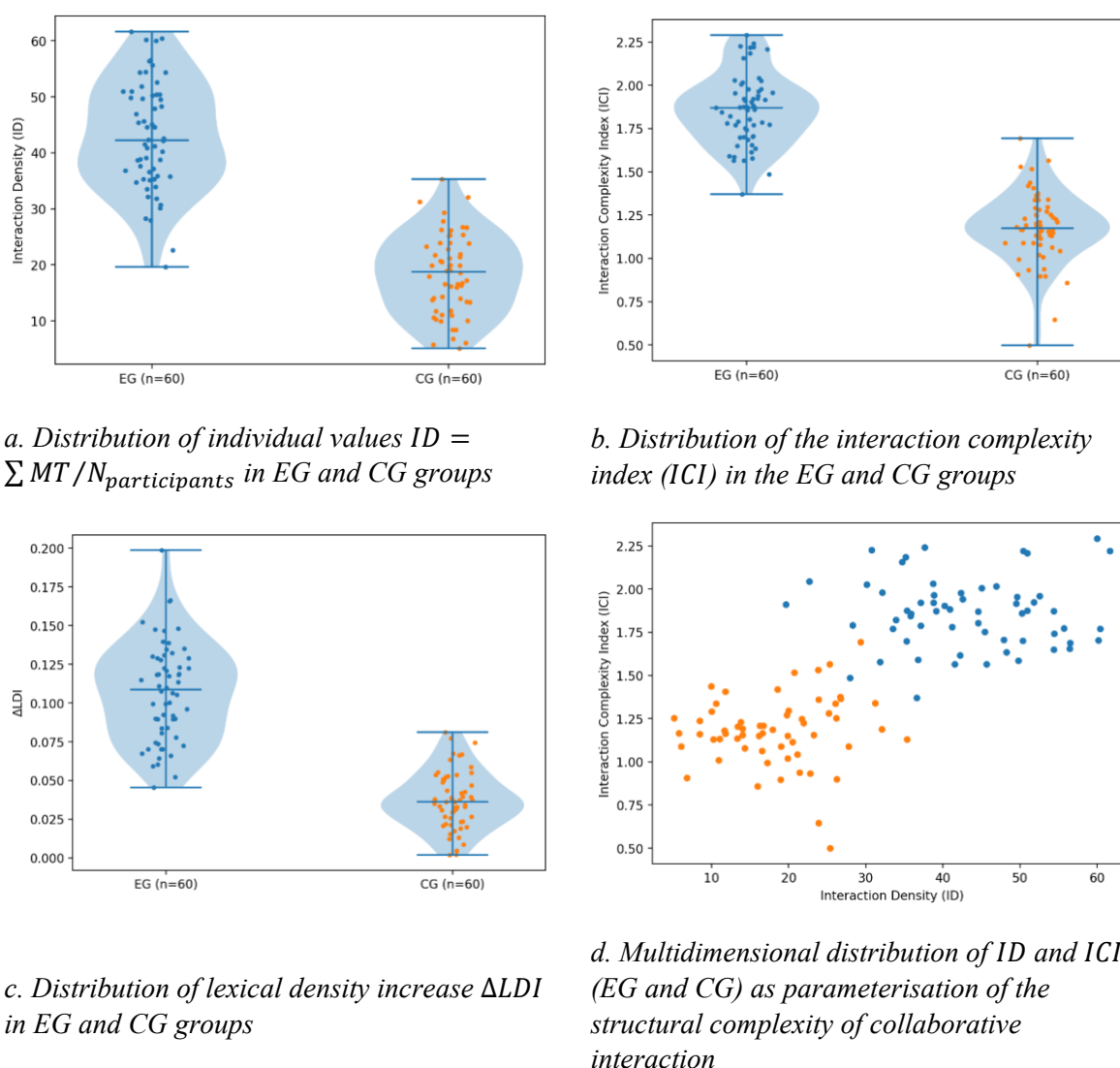
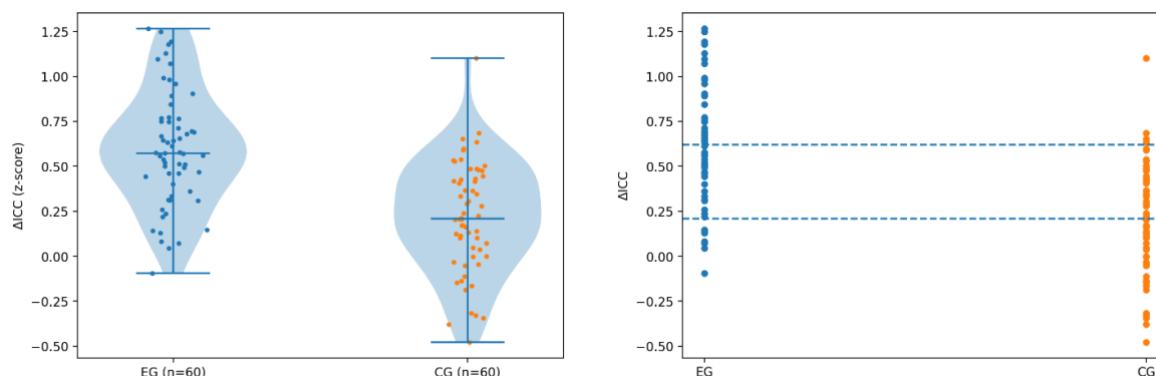


Fig 4. Parameterisation of collaborative interaction and multidimensional dynamics of indicators in the CCLE environment (N=120)

Source: developed by the authors

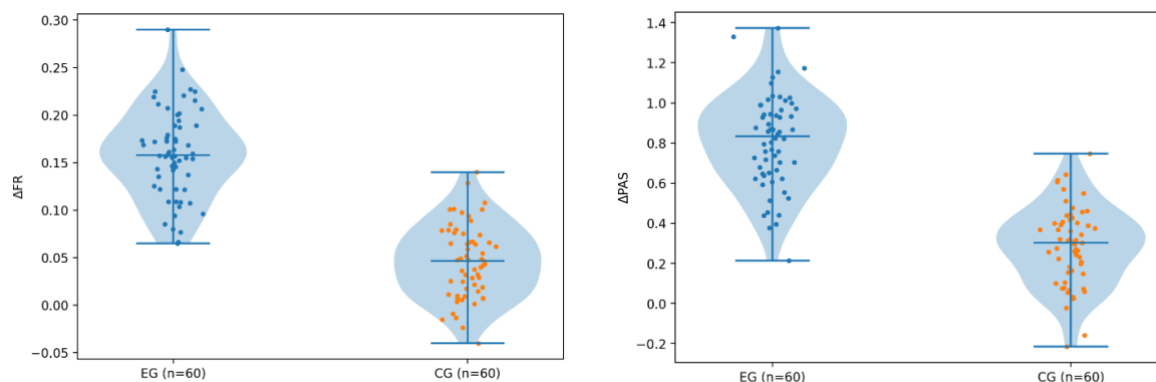
Analytical interpretation of the intervention configuration (Fig. 4) showed that CCLE (Fig. 3) generated systematic variation in learning interaction rather than functioning only as an organisational platform. Intergroup differentiation in Interaction Density (42.3 ± 8.1 vs. 18.7 ± 6.4 ; $p < 0.001$) indicated substantially greater exposure to content-relevant turns (Fig. 4a), while ICI values (1.84 vs. 1.21 ; $p = 0.004$) indicated greater syntactic-discursive complexity (Fig. 4b). The LDI increase ($+0.11$ vs. $+0.04$) was smaller in magnitude but directionally consistent with lexical diversification (Fig. 4c). The joint ID–

ICI distribution therefore supported an interactional pathway in which higher participation density co-occurred with structurally richer discourse (Fig. 4d). These process differences provided the analytical basis for testing whether the observed interaction profile was associated with the subsequent ICC gain rather than assuming that platform use itself produced the outcome.



a. Distribution of standardised increments ΔICC (z-score) in the EG and CG groups

b. Individual ΔICC values reflecting average effects (EG=0.62; CG=0.21)



c. Distribution of the increase in the ΔFR (Fluency Rate) indicator in the EG and CG groups

d. Distribution of ΔPAS (Pragmatic Adequacy Score) increase in EG and CG groups

Fig 5. Standardised gains in FLCC and component dynamics in CCLE conditions ($N = 120$)

Source: developed by the authors

The standardised ICC gain in the experimental group was +0.62 SD compared with +0.21 SD in the control group, with $t(118)=4.87$, $p<0.001$ and Cohen's $d=0.78$ (95% CI [0.41, 1.14]), providing evidence of a systematic intervention-associated difference (Fig. 5a, b). Component decomposition showed the strongest response in Fluency Rate (+15%) and Pragmatic Adequacy (+0.8/5), whereas lexical-density change was smaller (Fig. 5c, d). This asymmetry is pedagogically plausible: repeated time-bounded briefings, turn-taking and repair rapidly proceduralised accessible language and context-sensitive response patterns, whereas lexical diversification requires broader exposure, deliberate retrieval and repeated recycling of lower-frequency items. The result therefore indicates that CCLE primarily accelerated temporal-pragmatic adaptation during the intervention window; stronger lexical gains would likely require explicit lexical targets, spaced retrieval and corpus/data-driven follow-up tasks.

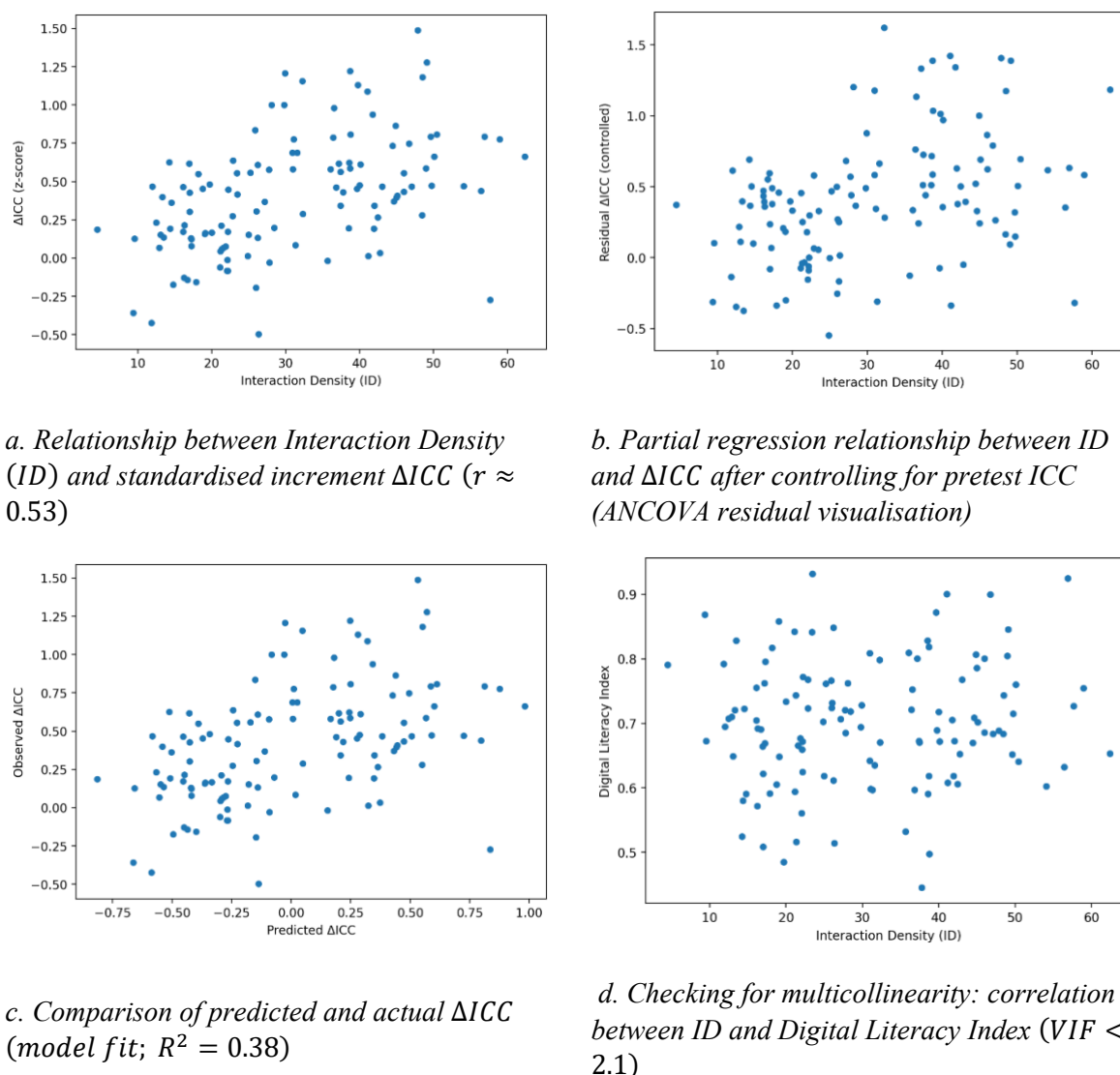


Fig 6. Multifactorial regression parameterisation of FLCC growth in CCLE conditions ($N = 120$)

Source: developed by the authors

The multifactorial model showed that ICC gain was not reducible to the EG/CG dichotomy. Interaction Density correlated with ICC gain at $r=0.53$ ($p<0.001$), and the adjusted coefficient remained significant after controlling for pretest ICC, digital literacy and academic performance ($\beta=0.41$, $p=0.002$) (Fig. 6a, b). Model fit accounted for 38% of outcome variance ($R^2=0.38$; $F(4,115)=17.6$; $p<0.001$), while VIF values below 2.1 indicated stable predictor separation (Fig. 6c, d). These results are consistent with the proposed mediation logic, but the quasi-experimental design does not exclude unmeasured teacher, motivation, engagement, novelty or institutional effects. Accordingly, the model provides evidence that interaction density contributed to competence growth rather than proof of an exclusive causal mechanism.

As a result of the study (Table 1), the parameterisation model linked FLCC change to measurable properties of collaborative interaction. The novel contribution is the joint operationalisation of Interaction Density, discourse complexity and standardised ICC gain, with $\Delta ICC=+0.62$ SD and an adjusted Interaction Density coefficient of $\beta=0.41$. The findings therefore extend technology-effectiveness research by showing that the pedagogically structured intensity and quality of digital interaction were associated with language-development outcomes beyond simple technology exposure.

Table 1. Comparative Analysis of Pretest/Posttest Intervention results

Metric	Pretest EG	Posttest EG	Δ EG	Pretest CG	Posttest CG	Δ CG	Effect / Conclusion
ICCtotal (z)	0.02	0.64	+0.62	0.01	0.22	+0.21	d=0.78; medium-high effect
FR (words/min)	118	136	+15%	120	126	+5%	Fluency acceleration in CCLE
PAS (0–5)	3.1	3.9	+0.8	3.2	3.5	+0.3	Pragmatic adequacy growth
LDI	0.51	0.62	+0.11	0.52	0.56	+0.04	Lexical diversification
ID	–	42.3	–	–	18.7	–	Interaction asymmetry
ICI	–	1.84	–	–	1.21	–	Structural discourse complexity

Source: developed by the authors

The results supported the research hypothesis regarding an interaction-mediated pathway to FLCC growth. The ICC increase co-occurred with a statistically significant predictive contribution of Interaction Density after adjustment for pretest performance and measured covariates. The evidence therefore supports, rather than definitively proves, the proposition that structural-interaction parameters of CCLE contribute to variation in language-learning outcomes.

3.2. Discussion

Comparative analysis of results is methodologically appropriate for determining the degree of incrementality and empirical novelty of the conclusions obtained in the context of contemporary research on TEL, ESP, and military language training. Most relevant works focused on conceptualising technological integration, needs analysis, or the adoption of digital tools without multidimensional statistical verification of competence gains. Thus, the comparative discussion allowed us to identify theoretical and methodological gaps and assess whether the CCLE model ensured the transition from a descriptive to a parameterised level of evidence.

First, the present findings align with meta-analytic evidence that educational technology is most effective when it operationalises language-learning processes rather than merely digitising delivery (Rahmati et al., 2021; Tao & Gao, 2022). The observed ICC gain and the independent contribution of Interaction Density specify one such process: repeated, meaningful participation. This interpretation is more consistent with Interaction Hypothesis and sociocultural accounts of negotiated meaning and scaffolded co-construction than with a technology-determinist explanation.

Second, the ID and ICI patterns extend collaborative-writing and peer-feedback findings. Elabdali (2021) and Vuogan and Li (2023) reported robust benefits of collaboration and peer feedback, while Chen and Lee (2022) showed that peer interaction can also generate conflict and uneven participation. In the current intervention, structured roles, rubrics and teacher mediation constrained this variability, yet the modest LDI gain relative to FR indicates that collaboration alone did not guarantee lexical expansion; process density benefited procedural fluency more rapidly than lexical breadth.

Third, the strong FR and PAS responses are compatible with technology-mediated TBLT. Canals and Mor (2023), Kim and Namkung (2024), and Kim et al. (2026) emphasised purposeful tasks, interaction, feedback and authentic outcomes as central design principles. Here, operational briefings, information-gap decisions and rank-sensitive pragmatic moves repeatedly imposed real-time communicative pressure, which plausibly explains why temporal-pragmatic adaptation outpaced lexical diversification. For ELT practice, the implication is to pair such tasks with explicit lexical priming and spaced retrieval rather than expecting vocabulary growth as an automatic by-product.

Fourth, the military findings refine evidence on institutional constraints. Hsu and Chao (2023) showed that military-base conditions can weaken perceived ease of mobile learning, whereas Siegel et al. (2024) identified substantial heterogeneity across military-English designs. The CCLE architecture addressed these constraints through role-based access, auditable task flows and asynchronous participation, but its effect should not be generalised mechanically beyond the studied institution. Transfer to university EFL or other professional ESP contexts requires re-specification of tasks, role relations, security requirements and baseline digital literacy.

Finally, AI-supported rehearsal should be interpreted cautiously. Pack and Maloney (2024), Yang and Li (2024), and Lo et al. (2024) documented both pedagogical affordances and ethical risks of

generative AI in TESOL. In this study, ChatGPT was limited to formative rehearsal, while teachers retained responsibility for task design, feedback and assessment; thus, the observed effect cannot be attributed to AI alone. This bounded implementation is particularly important in military education, where privacy, data classification and institutional accountability constrain open-cloud use.

Overall, prior studies supported technology-mediated interaction, task authenticity and feedback, but rarely connected process indicators to integrated FLCC change while controlling baseline covariates. The present results narrow this gap by linking ID/ICI process traces to LDI, FR, PAS and integral ICC outcomes within one pretest–posttest model. The pedagogical interpretation is therefore process-centred: productive outcomes were strongest where cadets repeatedly had to understand input, formulate a response under time constraints, negotiate meaning, receive feedback and reuse language in a revised artefact. For English and ESP teachers, the transferable principle is not a fixed vendor stack but a hybrid task cycle: face-to-face preparation and debriefing, cloud-mediated meaning negotiation, collaborative artefact production, peer/teacher feedback, and bounded AI rehearsal.

A balanced implementation should preserve face-to-face interaction for modelling, sensitive corrective feedback and high-stakes performance, while using cloud spaces for rehearsal, distributed participation, revision history and extended peer interaction. ID and ICI can help teachers diagnose under-participation or shallow interaction, but they should not become grading proxies because high message counts do not necessarily indicate accurate or pedagogically valuable language use. Such principles may transfer to university EFL and professional ESP, but effect sizes require independent replication because the military context combines unusually strong discipline, role hierarchy and professional communication specificity. In non-military settings, the professional scenario, participation rules and data-governance layer should be redesigned while retaining the underlying task-feedback-interaction sequence.

a) *Limitation*

The study was limited by a single-centre quasi-experimental design and N=120, which constrains external validity across military institutions, university EFL programmes and broader ESP settings. Although pretest ICC, digital literacy and academic performance were controlled, teacher effects, learner motivation, differential engagement, novelty effects and institutional conditions were not fully modelled. The 16-week duration also precluded conclusions about long-term retention, and ID/ICI captured observable interaction structure rather than the full cognitive quality of language processing. These limitations require the reported relationships to be interpreted as adjusted associations that provide evidence of effectiveness, not as definitive causal estimates.

b) *Recommendations*

Future research should use multicentre samples, longitudinal follow-up and multilevel/structural equation models to separate learner, teacher, unit and platform effects. Motivation, anxiety, engagement, feedback uptake and lexical-retrieval measures should be integrated with learning analytics to test mediation and moderation more directly. Follow-up measurements should distinguish short-term procedural fluency from durable lexical and pragmatic retention, while experimental variants should compare different ratios of synchronous, asynchronous and face-to-face interaction. Replication in university EFL and non-military ESP should preserve the pedagogical task cycle while adapting professional scenarios, access controls and feedback routines to the target context. Cross-context replication should also test measurement invariance of the FLCC index before comparing effect sizes, because the relative contribution of fluency, pragmatics, lexical density and interaction complexity may differ by proficiency level and professional domain.

4. Conclusions

Main results of the study. The quasi-experimental evidence indicated that participation in the CCLE condition was associated with a larger FLCC gain: +0.62 SD in the experimental group versus +0.21 SD in the control group, with $d=0.78$. The multivariate model explained 38% of the variance, and Interaction Density remained a significant predictor ($\beta=0.41$; $r=0.53$ with ICC gain), supporting the interpretation that structured collaborative participation contributed to the observed outcome. Component analysis showed greater sensitivity of fluency and pragmatic adequacy than lexical density, indicating that the 16-week design preferentially strengthened temporal-pragmatic performance.

The study's sequential logic linked psychometrically validated baseline measurement, a pedagogically specified intervention, process analytics and adjusted outcome modelling. The findings

showed that learning gains were associated not only with access to cloud technology but with the density, discourse complexity and feedback structure of interaction. This supports CCLE as a pedagogically orchestrated model of blended military language learning while preserving appropriate caution about unmeasured confounding.

The scientific novelty of the study lies in formalising and empirically testing the CCLE–Interaction Density–ICC Gain model as a language-pedagogical, not merely technological, mechanism. The model integrates SLA/TESOL principles with measurable interaction traces and multidimensional FLCC outcomes, enabling quantitative evaluation of how collaborative participation is associated with competence growth in a regulated blended environment.

The practical significance of the results. For ELT/ESP teachers, the findings support a hybrid sequence combining face-to-face preparation, synchronous briefing, asynchronous negotiation, collaborative writing, peer review and teacher feedback, with ID/ICI used as process-monitoring rather than achievement metrics. Implementation should begin with low-risk instructional scenarios, common rubric descriptors and explicit teacher moderation before analytics are used for course-level adjustment. Scaling the architecture requires institution-managed identities, role-based access, multifactor authentication, DLP/audit, pseudonymisation and network segmentation; classified or operationally sensitive content should remain outside public cloud and generative-AI services. Where military policy requires on-premise deployment, Moodle, collaboration tools and local/approved language models can replace public services without changing the pedagogical logic. This separation of pedagogical functions from vendors makes the architecture functionally portable but security-context dependent and permits gradual adoption without requiring wholesale replacement of existing military learning infrastructure.

Acknowledgment

Not applicable.

Declarations

- Author contribution** : Viktoriia Romaniuk initiated the research ideas, constructed the instruments, collected the data, drafted the manuscript, and reviewed the data analysis. Lidiia Nanivska contributed to the literature review and validated the instruments. Iryna Danchenko revised the research ideas and literature review, conducted the data analysis, and reviewed and edited the final draft. Olha Derbak organized the data and contributed to the interpretation of the findings. Halyna Namachynska assisted with data collection and transcription.
- Funding statement** : This research is not funded
- Conflict of interest** : The authors declare no conflict of interest.
- Ethics Declaration** : We as author acknowledge that this work has been written based on ethical research that conforms to the regulations of our university. We support ELTEJ Journal in maintaining high standards of personal conduct and practicing honesty in all our professional practices and endeavors.
- Additional information** : No additional information is available for this paper.

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