The Role of Cloud-Based Collaborative Tools in Fostering Digital Teamwork and Engagement in Undergraduate Computer Science Courses

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***Abstract*—Collaborative problem-solving is central to Computer Science (CS) education, yet CS-specific evidence on how Cloud-Based Collaborative Tools (CBCTs) relate to engagement and teamwork remains limited. This study examines student perceptions during a 15-week intervention in which 31 undergraduates used Google Workspace, Microsoft Teams, and Miro to complete labs, reports, and team projects. Post-intervention ratings were above the neutral midpoint on core engagement indicators—for example, Motivation ($M = 4.16$, $SD = 0.82$; $t(30) = 7.71$, $p < 0.001$) and Effective Contribution ($M = 4.00$, $SD = 1.00$)—while technology-acceptance judgments were closer to neutral (e.g., Productivity, $M = 3.06$). Qualitative responses highlighted benefits (real-time co-editing, quicker feedback) alongside coordination challenges (scheduling, role clarity). Overall, the patterns indicate that CBCT-supported practices align with higher engagement and contribution in CS coursework, while pointing to implementation levers—structured roles and feedback cadence—to strengthen acceptance. The study contributes CS-specific evidence and practical recommendations for integrating CBCTs in blended and online learning contexts.**

***Keywords*—Cloud-Based Collaborative Tools (CBCTs), computer science education, digital learning, student engagement, teamwork, technology acceptance**

I. Introduction

The integration of technology in education has transformed the way students learn, collaborate, and engage with course materials. In higher education, digital tools have become an essential component of teaching and learning, enabling more interactive, flexible, and student-centered approaches. As universities adopt blended and online learning models, technology-enhanced collaboration has become central to engagement and knowledge retention [1]. Digital learning environments support active participation, peer interaction, and shared knowledge construction [2].

With the increasing emphasis on teamwork and problem-solving skills in higher education, institutions are increasingly adopting digital tools to facilitate communication, group work, and project management. Traditional classroom-based collaboration, which relies on face-to-face discussions and physical resources, is often constrained by time and space limitations. Digital collaboration tools address these challenges by providing real-time communication, document sharing, and task management functionalities that enhance efficiency and engagement [3]. Empirical work links digital collaborative environments with higher motivation, participation, and self-regulation [4].

Among the various technological solutions available, Cloud-Based Collaborative Tools (CBCTs) have gained prominence in supporting student learning and teamwork. CBCTs enable seamless communication, document co-editing, and asynchronous collaboration, making them particularly useful for project-based and group-oriented coursework. These tools provide a shared workspace where students can contribute in real time, track progress, and engage in peer discussions, fostering a sense of co-ownership and accountability in their learning process [5]. They also reduce logistical barriers by supporting multi-device, and anytime access.

Several widely used CBCTs have been adopted in educational settings to enhance collaborative learning experiences. Google Workspace, including Google Docs, Sheets, and Slides, allows students to co-edit documents in real time, leave comments, and provide peer feedback, supporting collaborative writing and brainstorming activities [6]. Microsoft Teams integrates video conferencing, file sharing, and task management, providing a centralized platform for group discussions, project coordination, and instructor-student interaction [7]. Miro Board, a digital whiteboarding tool, enables students to create visual representations of ideas, engage in mind mapping, and facilitate remote brainstorming, making it particularly beneficial for creative and design-oriented disciplines [8].

The adoption of these tools in higher education is driven by their ability to improve communication, increase student engagement, and enhance collaborative problem-solving. Yet in Computer Science (CS) education, comparatively few studies jointly examine how CBCTs relate to both engagement and collaboration outcomes. This study aims to fill that gap by assessing the impact of CBCTs on student engagement, teamwork, and learning outcomes in computer science courses.

Despite the increasing use of collaborative learning approaches in higher education, students continue to face significant challenges in group-based work. One of the primary issues is lack of engagement, where students often exhibit passive participation in group activities, leading to unequal contributions and imbalanced workload

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distribution [9]. Many students struggle with ineffective communication, particularly in online or asynchronous settings, where delays in responses and misunderstandings can hinder the progress of group tasks [10]. Furthermore, task coordination difficulties arise when group members lack a structured approach to assigning roles, tracking project progress, and managing deadlines, which can lead to disorganization and inefficiencies [11]. These persistent issues motivate structured, tool-supported teamwork approaches.

Traditional collaborative approaches, such as in-person group work and standard Learning Management Systems (LMSs), are often limited in addressing these challenges. While in-person collaboration provides immediate interaction and engagement, it is constrained by time, location, and scheduling conflicts, making it difficult for students to coordinate meetings effectively [12]. Similarly, conventional LMS platforms, such as Moodle and Blackboard, primarily function as content delivery systems rather than dynamic collaboration spaces, offering limited interactive features beyond discussion forums and file uploads [13]. As a result, students using these traditional methods may experience reduced engagement, delayed feedback, and inefficient collaboration, ultimately affecting their learning outcomes. CBCTs are designed to address precisely these limitations.

To overcome these limitations, CBCTs have been proposed as an alternative to enhance teamwork and engagement in digital learning environments. However, while CBCTs such as Google Workspace, Microsoft Teams, and Miro Board have gained widespread adoption, there remains a gap in research regarding their effectiveness in higher education, particularly in computer science education. Previous studies have focused on general perceptions of digital collaboration or specific technical functionalities of CBCTs, but few have conducted a comprehensive empirical analysis of their impact on student engagement, teamwork, and learning effectiveness [14]. Accordingly, we examine pre/post changes in engagement and collaboration and explore associations among key variables in a CS setting.

Given the increasing emphasis on collaborative problem-solving and digital literacy in computer science education, understanding how CBCTs influence student engagement and teamwork is critical. This study aims to address this research gap by evaluating the impact of CBCTs on student participation, communication effectiveness, and learning outcomes in computer science courses. By assessing pretest and posttest changes, as well as conducting correlation analysis between collaboration-related variables, this study will provide empirical evidence on the effectiveness of CBCTs in fostering meaningful student interaction. Additionally, by incorporating qualitative insights from student feedback, this research will offer practical recommendations for improving the implementation of CBCTs in higher education. This dual focus on quantitative change and qualitative experience underpins our practical guidance for instructors.

This study distinguishes itself from previous research by providing empirical evidence on the impact of CBCTs on student engagement, collaboration, and technology acceptance in higher education. While prior studies have explored the general benefits of online collaboration tools, few have systematically assessed their direct influence on engagement and teamwork using pretest-posttest comparisons. By measuring students' engagement levels before and after CBCT implementation, this research offers quantitative insights into how these tools affect participation, motivation, and group interaction. Additionally, the study extends beyond self-reported perceptions by integrating correlation analysis between key engagement variables, which has not been extensively examined in previous CBCT-related research. We report reliability for scales and align analyses explicitly to each research question.

A key novelty of this study lies in its mixed-methods approach, which combines statistical analysis of pretest and posttest survey data with qualitative thematic analysis of student feedback. This dual-method approach ensures a comprehensive understanding of CBCTs' effectiveness, capturing both measurable changes in engagement levels and students' subjective experiences. While many existing studies rely solely on survey-based perceptions of technology use, this research enhances validity by incorporating paired t-tests to determine significant differences in engagement levels and thematic coding of open-ended responses to identify patterns in student experiences. This methodological combination enables a richer exploration of how CBCTs influence student collaboration beyond numerical data.

Another significant contribution of this study is its specific focus on undergraduate computer science students, a group that relies heavily on teamwork, digital literacy, and problem-solving skills. While CBCT adoption has been explored in general education and business courses, its role in computer science education remains underexplored. Given the increasing need for collaborative problem-solving in software development, algorithm design, and computational thinking, understanding how CBCTs support teamwork in this field is critical. By targeting this discipline, the study provides discipline-specific insights that can help educators design more effective collaboration strategies for technical courses.

Furthermore, this study offers a detailed correlation analysis examining relationships between key engagement variables, such as collaboration frequency, ease in group assignments, motivation, and learning effectiveness. While previous research has acknowledged that digital tools enhance engagement, few studies have quantified the strength of these relationships to understand which factors contribute most to student success in CBCT-supported learning environments. By identifying which engagement factors are most strongly associated with learning outcomes, this research provides data-driven insights that can inform the future development of digital collaboration strategies in higher education.

Finally, this study contributes to practical recommendations for improving CBCT implementation in academic settings. The analysis of students' qualitative feedback highlights real-world challenges in using CBCTs, such as task coordination difficulties and communication barriers. By addressing these challenges, this study offers evidence-based recommendations for optimizing the use of CBCTs in university courses, including structured task management, clearer communication protocols, and improved integration with learning management systems. These findings can benefit educators, instructional designers, and academic institutions looking to maximize the potential of cloud-based tools in fostering engagement and teamwork.

By bridging the gap between quantitative evidence, qualitative insights, and practical recommendations, this study presents a novel contribution to the understanding of CBCTs in higher education and computer science pedagogy.

This study investigates the impact of Cloud-Based Collaborative Tools (CBCTs) on student engagement, teamwork, and learning outcomes in computer science education. Specifically, it assesses engagement in collaborative learning (participation, motivation, teamwork effectiveness); evaluates students' perceptions of CBCTs (perceived ease of use, perceived usefulness, and adoption); analyzes relationships among collaboration, motivation, and learning outcomes during group-based coursework; identifies challenges and limitations students encounter when using CBCTs; and offers practical recommendations for optimizing CBCT implementation in higher education, particularly in computer science courses.

To achieve these objectives, the study is guided by the following research questions:

1) How do CBCTs affect student engagement and participation in collaborative learning?
2) What are students' perceptions of CBCTs in terms of ease of use, usefulness, and overall effectiveness?
3) What are the challenges students face when using CBCTs for learning and group work?
4) What is the relationship between collaboration frequency, motivation, and learning outcomes in CBCT-supported learning environments?
5) How can CBCT implementation be improved to enhance student engagement and teamwork in higher education?

By addressing these research questions, this study seeks to provide empirical evidence on the effectiveness of CBCTs in fostering engagement, collaboration, and academic success. The findings will contribute to pedagogical strategies for integrating digital collaboration tools into computer science education and other disciplines where teamwork and problem-solving skills are critical.

This study contributes to the field of computer science education and digital pedagogy by providing empirical evidence on the role of CBCTs in enhancing student engagement, teamwork, and learning outcomes. As collaborative problem-solving and digital literacy become essential competencies for computer science students, understanding how CBCTs facilitate these skills is critical for designing effective instructional strategies. This research highlights how technology-enhanced collaboration can improve student participation, streamline group work, and foster a more interactive and engaging learning environment.

The findings of this study hold valuable implications for educators, curriculum developers, and higher education institutions seeking to integrate digital collaboration tools into their teaching practices. By identifying how CBCTs impact student engagement and learning effectiveness, this research can guide educators in selecting appropriate tools, structuring group activities, and designing assessments that maximize collaborative learning experiences. Curriculum developers can leverage these insights to create more interactive course designs that align with industry demands for teamwork and technological proficiency. Additionally, institutions can use the study's recommendations to enhance digital learning policies, provide training for faculty and students, and invest in technology infrastructure that supports seamless virtual collaboration.

For students, the adoption of CBCTs presents multiple educational benefits, including improved teamwork, participation, and overall learning experiences. The study demonstrates that when students actively use CBCTs, they develop stronger communication skills, better project management abilities, and a greater sense of responsibility in group work. Furthermore, these tools facilitate equal participation by enabling all members to contribute, track progress, and provide feedback in real time. This is particularly important in computer science education, where collaborative coding, problem-solving, and project-based assignments are integral to learning. By improving students' ability to work in teams and manage tasks efficiently, CBCTs help prepare them for professional environments where digital collaboration is a fundamental skill.

The relevance of this study is further emphasized in the context of blended and online learning environments, which have become increasingly prevalent in higher education. With many universities adopting hybrid learning models, where students engage in both face-to-face and online interactions, the need for effective digital collaboration tools has grown significantly. This research provides data-driven insights into how CBCTs can support engagement in these learning settings, offering solutions to common challenges such as disengagement, poor communication, and ineffective group coordination. By addressing these issues, this study contributes to the broader conversation on enhancing student collaboration in digital learning spaces, ensuring that higher education institutions can adapt to the evolving demands of remote and technology-driven education.

By bridging the gap between technological innovation and pedagogical practices, this study not only expands the theoretical understanding of CBCTs in education but also offers practical recommendations for improving digital learning environments. The findings will serve as a valuable resource for educators, researchers, and policymakers who aim to harness cloud-based collaboration to optimize student learning and engagement in computer science and beyond.

II. Literature Review

We focus this review on CBCT affordances, adoption, and outcomes most relevant to higher education and CS coursework [15].

CBCTs align with established learning theories emphasizing social knowledge construction. Vygotsky's Social Constructivism posits that learning occurs through peer and instructor interaction [16]. Similarly, Collaborative Learning Theory highlights structured teamwork and active student participation [17]. The Community of Inquiry (CoI) framework identifies cognitive, social, and teaching presence as critical for online collaboration [18], while the Technology Acceptance Model (TAM) explains that perceived usefulness and ease of use determine CBCT adoption [19]. These models support CBCTs as dynamic tools fostering engagement and teamwork in digital learning environments.

CBCTs enhance collaborative learning by enabling synchronous and asynchronous interaction, document co-editing, and task management. Tools such as Google Workspace, Microsoft Teams, and Miro Board provide real-time collaboration, peer feedback, and workflow management [20]. Research highlights their benefits in improving student coordination, communication, and engagement in project-based learning [21, 22]. CBCTs can promote equity by allowing students to contribute asynchronously while fostering accountability through real-time tracking features [23].

A growing body of CS-specific work shows how CBCTs map directly onto programming and project workflows. Large-scale survey evidence indicates that using GitHub in the classroom predicts higher self-reported learning and preparedness, and that receiving feedback via GitHub further increases perceived benefits [24]. Instructors also report that GitHub Classroom operationalizes collaboration and assessment through pull-request-based feedback, template repositories, and integrated continuous-integration pipelines—features that scaffold teamwork and iterative review at scale [25]. Complementing code-hosting platforms, Slack has been used across multiple Computer Science (CS) and Electrical and Computer Engineering (ECE) courses to improve day-to-day communication and project coordination; end-of-semester surveys showed students agreed Slack enhanced information sharing, Questions and Answers (Q&A), and collaboration [26].

CBCTs might enhance engagement across behavioral, emotional, and cognitive dimensions [27]. Behavioral engagement increases through participation and teamwork [28], while emotional engagement improves due to a sense of community and instant feedback [29]. CBCTs might also promote cognitive engagement by enhancing problem-solving and critical thinking [30, 31]. Furthermore, they support digital literacy and project management skills, preparing students for professional environments [32, 33].

Beyond messaging and repositories, cloud-hosted computational environments lower setup barriers and support team-based problem solving. In a team-based Python course using cloud notebooks, students reported increased motivation and confidence, with the format fostering collaborative engagement while ensuring equitable access (no local installs required) [34]. In parallel, Web-of-Things/IoT remote laboratories (LoT@UNED) embedded in CS disciplines demonstrate measurable gains: students' average marks rose from 63.70 to 78.18 with a significant pre–post difference ($t = -7.46$, $p < .005$), alongside strong participation analytics—evidence that cloud-mediated labs can reinforce engagement and outcomes in computing courses [35].

Despite their advantages, CBCT implementation faces technical barriers, such as internet connectivity and software compatibility [36, 37]. The lack of training for students and educators often leads to suboptimal use [38]. Resistance to digital collaboration and difficulties in task coordination can reduce engagement [39, 40]. Moreover, issues like unequal participation [41], digital distractions, and over-reliance on technology further complicate CBCT adoption [42, 43].

While emerging CS-specific studies document benefits of GitHub, Slack, cloud notebooks, and IoT-enabled remote labs, this evidence is often fragmented—focusing on a single platform, lacking pre/post designs, or omitting links to acceptance constructs; our study extends this literature with a mixed-methods, within-course pre/post evaluation that triangulates engagement, collaboration, and technology acceptance in a single CS cohort.

III. Methodology

This study investigates the impact of CBCTs on student engagement, teamwork, and learning outcomes in computer science education. A single-group pretest-posttest design was employed, where students used CBCTs over a 15-week period, and their engagement and collaboration levels were assessed before and after the intervention. The study adopts a mixed-methods approach, incorporating both quantitative and qualitative analyses to evaluate the effectiveness of CBCTs. All participants actively used CBCTs (Google Workspace for co-authoring/submission, Microsoft Teams for communication/scheduling, and Miro for visual ideation and design sprints), with tools selected for task-specific affordances rather than as interchangeable platforms. Given institutional constraints (intact cohorts, equity of access) and the pedagogical goal of studying authentic practice in situ, a single-group pretest–posttest design was used; we therefore interpret changes as associations rather than causal effects and avoid causal wording throughout (see Limitations). To mitigate single-group threats (maturation, history, testing), we (i) pre-specified a fixed assessment schedule, (ii) triangulated with qualitative data, and (iii) report internal consistency for all scales at pre- and post-test. Where feasible, we will provide a descriptive benchmark to a prior offering without mandatory CBCT use (archival, non-overlapping cohort), emphasizing that such contrasts are exploratory and non-causal.

The study was conducted with 31 undergraduate students enrolled in computer science courses at L. N. Gumilyov Eurasian National University and S. Amanzholov East Kazakhstan University. The participant group comprised 58.1% male and 41.9% female students, with a pre-study survey revealing that most had minimal prior experience using CBCTs. Participation was voluntary, and all students provided informed consent before data collection. The intervention ran across core undergraduate CS offerings at both institutions; activity patterns were aligned across offerings (task setting, communication protocols, co-authoring, peer review, and project coordination) to ensure comparable exposure to CBCT-supported teamwork.

To assess the impact of CBCTs, data collection relied on a structured survey incorporating three validated scales: the Student Engagement Scale, the Collaboration Scale, and the TAM Scale. The Student Engagement Scale measured both behavioral engagement, such as participation and attendance, and emotional engagement, including motivation and interest in learning activities. The Collaboration Scale focused on students' ability to work effectively in teams, emphasizing teamwork, communication, and task participation. The TAM Scale assessed perceived usefulness, ease of use, and attitudes toward CBCTs. All survey items were rated on a five-point Likert scale, ranging from strongly disagree to strongly agree. In addition to quantitative data collection, open-ended questions were included in the post-study survey to capture students' perceptions, challenges, and recommendations regarding the use of CBCTs.

The study was conducted in three distinct phases. During the pre-study phase, students were introduced to CBCTs and completed a pretest survey measuring their initial engagement levels, collaboration experiences, and perceptions of technology. The intervention phase, spanning 15 weeks, required students to actively use CBCTs for collaborative learning in their coursework, completing weekly assignments and group projects through real-time collaboration tools such as Google Workspace, Microsoft Teams, and Miro Board. Weekly cadence comprised lecture plus lab/seminar, with CBCT use required for team deliverables and participation. In the post-study phase, a posttest survey was administered to evaluate changes in engagement, collaboration, and technology acceptance (Table 1). Additionally, students provided qualitative feedback through open-ended responses, describing their experiences with CBCTs, the challenges they encountered, and their suggestions for improving collaborative learning.

Table 1. Survey instrument and measurement scales

Section		Question
Student Engagement	1. I consistently attended classes for this course.	1–5 Scale
	2. I completed all assignments on time.	1–5 Scale
	3. I actively participated in class activities and discussions.	1–5 Scale
	4. I find the content of this course interesting.	1–5 Scale
	5. I feel excited about learning new topics in this course.	1–5 Scale
	6. I am motivated to do well in this course.	1–5 Scale
Collaboration (cloud-based collaborative tools)	1. I frequently collaborated with my classmates using cloud-based collaborative tools	1–5 Scale
	2. It was easy to work together on group assignments using cloud-based collaborative tools.	1–5 Scale
	3. I felt connected to my classmates when using cloud-based collaborative tools	1–5 Scale
	4. Communication within my group was effective using cloud-based collaborative tools.	1–5 Scale
	5. Collaborative activities using cloud-based collaborative tools enhanced my understanding of the course material.	1–5 Scale
	6. I was able to contribute effectively to group projects using cloud-based collaborative tools.	1–5 Scale
	7. Cloud-based collaborative tools facilitated equal participation among group members.	1–5 Scale
	8. I received timely feedback from peers through cloud-based collaborative tools.	1–5 Scale
Perceived Effectiveness of cloud-based collaborative tools	1. Using cloud-based collaborative tools improved my productivity in this course.	1–5 Scale
	2. Cloud-based collaborative tools improved the quality of my work.	1–5 Scale
Open-Ended Questions	1. What did you like most about using cloud-based collaborative tools in this course?	Open-ended
	2. What challenges did you encounter while using cloud-based collaborative tools?	Open-ended
	3. How do you think using cloud-based collaborative tools affected your learning and academic performance?	Open-ended
	4. Do you have any suggestions for improving the use of cloud-based collaborative tools in future courses?	Open-ended

The effectiveness of CBCTs was assessed using both quantitative and qualitative analysis techniques. For the quantitative analysis, descriptive statistics such as mean scores, standard deviations, and the percentage of positive responses were calculated. Paired t-tests were conducted to determine whether CBCTs had a statistically significant impact on student engagement and collaboration by comparing pretest and posttest scores. The reliability of the survey scales was evaluated using Cronbach's alpha, with a threshold of 0.75 indicating acceptable internal consistency.

For the qualitative analysis, open-ended responses were analyzed using thematic coding to identify recurring patterns in students' experiences, challenges, and perceptions of CBCTs. This mixed-methods approach provided a comprehensive understanding of the effectiveness of CBCTs in fostering student engagement and collaborative learning.

IV. Results

To avoid causal wording given the single-group design, we report observed score levels and associations for engagement, collaboration, and technology acceptance. The results are presented through a combination of quantitative analysis from pretest and posttest survey responses, as well as qualitative insights obtained from open-ended feedback. To aid traceability, each subsection notes the Research Question (RQ) addressed.

A. Changes in Student Engagement and Collaboration

The comparison of pretest and posttest mean scores, as illustrated in Fig. 1, indicates notable improvements across all measured dimensions. The posttest results show increased scores in key areas such as equal participation, effective contribution, communication, collaboration frequency, and motivation. Specifically, students reported higher ease in group assignments and greater class participation after using CBCTs. These findings suggest that the integration of collaborative digital tools enhanced students' ability to work effectively in teams and improved their overall engagement in coursework.

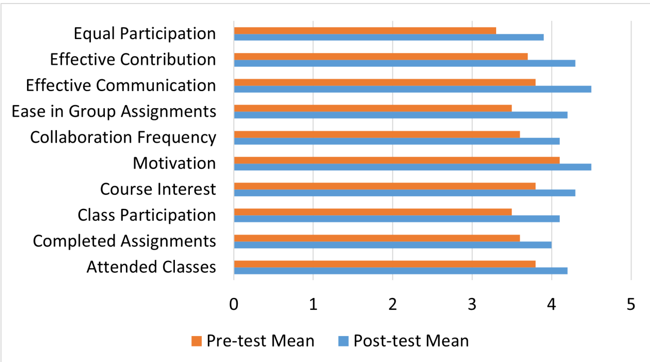

Fig. 1. Pre-test vs. post-test comparison of student engagement and collaboration.

Across weekly programming labs, collaborative reports, and team projects, students used Google Workspace for co-authoring/version history, Microsoft Teams for coordination, and Miro for visual ideation. Descriptive statistics ($N = 31$) showed above-neutral ratings for key engagement indicators: Attended Classes $M = 3.81$, $SD = 0.74$, $t(30) = 5.99$, $p < 0.001$; Class Participation $M = 3.55$, $SD = 1.12$, $t(30) = 2.74$, $p = 0.011$; Course Interest $M = 3.87$, $SD = 0.85$, $t(30) = 5.73$, $p < 0.001$; Motivation $M = 4.16$, $SD = 0.82$, $t(30) = 7.71$, $p < 0.001$. Collaboration measures were likewise positive: Effective Contribution $M = 4.00$, $SD = 1.00$, $t(30) = 5.57$, $p < 0.001$; Ease in Group Assignments $M = 3.48$, $SD = 1.18$, $t(30) = 2.28$, $p = 0.030$; Timely Feedback $M = 3.52$, $SD = 1.12$, $t(30) = 2.56$, $p = 0.016$.

B. Technology Acceptance and Perceived Benefits

Students' perceptions of CBCTs were evaluated using the TAM, with results presented in Fig. 2. The findings indicate that students perceived CBCTs as beneficial for enhancing productivity, improving work quality, and facilitating learning. Productivity enhancement received the highest rating, followed closely by improved work quality and user-friendliness. TAM outcomes were near the scale midpoint: Productivity Enhancement M = 3.06, SD = 1.03, $t(30) = 0.35$, $p = 0.730$; Improved Work Quality M = 3.32, SD = 1.11, $t(30) = 1.62$, $p = 0.115$; Learning Effectiveness M = 3.42, SD = 1.34, $t(30) = 1.75$, $p = 0.091$.

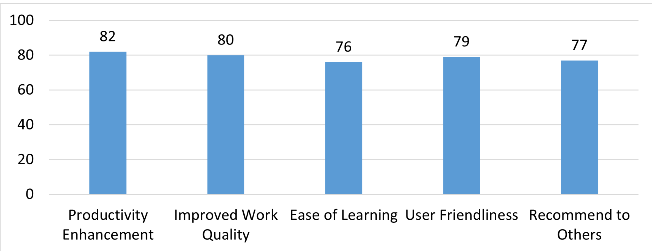

Fig. 2. Technology Acceptance Model (TAM) results.

C. Correlation Analysis of Key Variables

The relationships between various engagement, collaboration, and technology acceptance variables were further analyzed using correlation analysis, as shown in Fig. 3.

The results reveal strong positive correlations between collaboration frequency, ease in group assignments, and effective communication. Additionally, the analysis indicates that motivation is moderately associated with course interest and participation levels. Interestingly, students who reported higher engagement in collaborative activities were also more likely to perceive CBCTs as enhancing their learning effectiveness. Key coefficients: Effective Contribution and Timely Feedback ($r = 0.56$); Completed Assignments and Motivation ($r = 0.47$); lowest, Class Participation and Connection to Classmates ($r = -0.46$); near-zero, Effective Communication and Enhanced Understanding ($r = 0.04$).

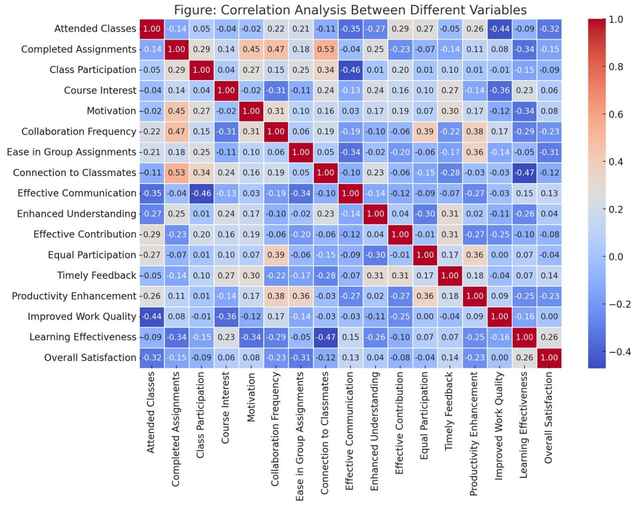

Fig. 3. Correlation analysis between different variables.

D. Qualitative Insights from Student Feedback

Thematic analysis of open-ended responses provides deeper insights into students' experiences with CBCTs. Table 2: Thematic Analysis of Student Feedback summarizes key themes extracted from student responses. Many students highlighted the advantages of CBCTs in fostering engagement and social interaction, emphasizing that real-time collaboration made group work more dynamic and connected. However, some students faced challenges related to time management and scheduling conflicts, indicating a need for structured meeting organization. Collaboration and teamwork were generally viewed positively, though some students noted difficulties in task delegation and tracking responsibilities.

Table 2. Thematic analysis of student feedback

Theme	Summary of Student Feedback
Engagement & Social Interaction	Students enjoyed face-to-face discussions, feeling more connected and engaged in group work. The natural flow of conversations and brainstorming made collaboration feel more dynamic.
Challenges & Time Management	Scheduling conflicts and time management were major challenges. Many students found it difficult to coordinate meetings and track tasks efficiently, leading to delays and disorganization.
Collaboration & Teamwork	Collaboration was highly valued, with students appreciating teamwork and the ability to share ideas freely. However, issues such as lack of structured task delegation led to confusion post-meetings.
Learning & Productivity	Students felt that CBCT helped them develop communication and teamwork skills but noted that productivity was sometimes lower due to disorganization and inefficiencies in meeting follow-ups.
Technology & Tools	Students mentioned challenges with communication outside of meetings due to the lack of a common platform. Some suggested using more digital tools, such as shared task lists or whiteboards, to improve tracking.
Suggestions for Improvement	Many students suggested structured meeting agendas, better task tracking, designated team roles, and clearer action plans. Fun elements, like themed meetings and interactive task assignments, were also proposed.

In terms of learning and productivity, students acknowledged that CBCTs helped improve their communication and teamwork skills but mentioned occasional inefficiencies in meeting follow-ups. Technology-related challenges, such as the lack of a unified platform for communication, were also cited. To address these issues, students suggested clearer task tracking mechanisms, structured meeting agendas, and the integration of more digital tools for workflow management.

E. Summary of Findings

Overall, engagement and collaboration indicators were above the neutral midpoint with several statistically significant differences (e.g., Motivation; Effective Contribution), while TAM outcomes were closer to neutral. Correlations highlighted the centrality of contribution and feedback to students' collaborative experience. Given the single-group design, results are interpreted as associations rather than causal effects; nonetheless, the converging quantitative and qualitative evidence points to concrete areas where CBCT-supported practices (e.g., structured feedback cycles, role clarity) are most impactful.

V. Discussion

Taken together, the results indicate higher ratings on several engagement and collaboration indicators and neutral-to-positive technology-acceptance perceptions in this undergraduate computer science cohort. Interpreted through Social Constructivism and the Community of Inquiry (CoI), the observed patterns are consistent with the idea that structured peer interaction (social presence) and coordinated task work (teaching presence) support learners' participation and contribution (cognitive presence).

Analyses showed statistically higher scores relative to the neutral midpoint for participation, effective contribution, and motivation; we therefore describe associations between CBCT-supported activities and these outcomes rather than causal improvements. This aligns with prior CS-education reports where cloud collaboration (e.g., code hosting, shared documents, lightweight communication) is linked with teamwork practices and iterative feedback.

From a Technology Acceptance Model (TAM) perspective, Perceived Ease of Use and Perceived Usefulness were close to the scale midpoint, suggesting moderate acceptance rather than uniformly high ratings. A plausible mechanism is that platform affordances (Google Workspace for co-authoring/version history, Microsoft Teams for coordination, Miro for visual ideation) increased opportunities for feedback and contribution, which correlated with learning-related judgments, while setup and coordination costs may have limited stronger Perceived Ease of Use (PEOU)/Perceived Usefulness (PU) responses.

Qualitative accounts echo this mechanism: students valued real-time co-editing and feedback cycles, but noted scheduling and role-clarity frictions—factors that theory would predict reduce PEOU/PU and, by CoI logic, weaken social or teaching presence when norms are underspecified. Correlations highlighted the centrality of contribution and feedback (the strongest associations), reinforcing the theoretical claim that structured interaction—not merely tool access—underpins engagement and perceived learning.

Conceptual synthesis. We propose a simple model linking activities → platforms → mediators → outcomes for undergraduate CS courses: (a) activities (weekly programming labs, collaborative reports, team projects) enacted by (b) task-specific platforms (Docs/Sheets for co-authoring; Teams for coordination; Miro for visual planning) influence (c) mediators—TAM constructs (PEOU/PU) and CoI presences (social/teaching/cognitive)—which in turn relate to (d) outcomes (participation, effective contribution, feedback, learning effectiveness). This model clarifies where instructional levers (role assignment, feedback cadence, shared task boards) act.

Design rationale and validity. The single-group pretest–posttest design was adopted to preserve intact cohorts and equitable access while embedding CBCT use in authentic coursework. We therefore avoid causal language and acknowledge threats to internal validity (maturation, history, testing effects). Mitigations included a fixed assessment schedule, common activity structure across weeks, and triangulation with qualitative themes; where available, descriptive contrasts to a prior offering without mandated CBCT use can contextualize change but remain non-causal.

Despite the valuable insights provided by this study, several limitations must be acknowledged.

Design and internal validity. This study used a single-group pretest–posttest design without a control group; maturation, history, and testing effects therefore cannot be ruled out, and all inferences are associative rather than causal. The design was adopted to preserve intact cohorts and equitable access while embedding CBCT use in authentic coursework. We therefore avoid causal language and acknowledge threats to internal validity. Mitigations included a fixed assessment schedule, common activity structure across weeks, and triangulation with qualitative themes; where available, descriptive contrasts to a prior offering without mandated CBCT use can contextualize change but remain non-causal.

Scope and generalizability. The sample size of 31 undergraduate computer science students may limit generalizability to broader student populations across different disciplines. While the findings provide important insights into CBCT adoption in technical education, future research should include larger and more diverse samples, including students from different academic fields and institutions, to determine whether similar engagement trends emerge across disciplines. Moreover, our context (undergraduate CS; 15-week term) and specific activity profile (labs, reports, projects) constrain generalization to other student types or course formats.

Measurement. Self-reported survey data were used as the primary measure of engagement, collaboration, and technology acceptance. Although validated scales were employed to enhance reliability, self-reported responses may introduce bias, as students might overestimate their engagement levels or provide socially desirable responses. Future studies could incorporate behavioral analytics, activity tracking logs, and observational data to obtain more objective measures of engagement and teamwork dynamics. Linking platform analytics (e.g., document revision histories, message logs, board edits) to survey constructs would strengthen convergent validity.

Technology access. Another limitation concerns technology dependency and accessibility. While CBCTs offer powerful collaboration capabilities, students in lower-resource settings or with unstable internet access may face barriers to participation. Future research should examine the digital divide in CBCT adoption, identifying strategies to make these tools more inclusive and adaptable to varied technological infrastructures.

Analytic scope. Finally, while the study provides correlation analysis between engagement variables, it does not establish causality between CBCT use and student performance. Future research should explore longitudinal effects of CBCT integration, examining how extended exposure to digital collaboration tools influences academic achievement, skill development, and career readiness. Including acceptance constructs (PEOU/PU) and CoI indicators as potential mediators in longitudinal models would clarify mechanisms.

VI. Conclusion

This study documents higher ratings on several engagement and collaboration indicators and neutral-to-positive acceptance perceptions in an undergraduate CS cohort engaged in 15 weeks of CBCT-supported labs, reports, and team projects (Google Workspace for co-authoring, Microsoft Teams for coordination, Miro for visual planning). Analyses showed differences relative to the neutral midpoint for participation, effective contribution, and motivation, and correlations emphasized the role of feedback and contribution in perceived learning. TAM outcomes were closer to neutral, indicating room to improve perceived usefulness and ease via clearer role structures and streamlined coordination.

While these findings highlight the potential of CBCT-supported practices, they also underscore challenges, including task coordination difficulties, unequal participation, and digital distractions. Thematic analysis of qualitative feedback revealed that while students appreciated flexibility and accessibility, many struggled with time management, platform inconsistencies, and reliance on digital communication; practically, instructors can prioritize structured feedback cycles, explicit role assignment, and shared task boards to strengthen social and teaching presence and, by extension, TAM perceptions.

Based on the findings and limitations of this study, several directions follow in prose rather than list form. Institutions should enhance CBCT implementation strategies by developing structured guidelines for task delegation, group management, and time-tracking, with peer-evaluation and progress-tracking features to support accountability. Faculty and student training programs remain important to equip users with virtual teamwork, workflow management, and troubleshooting skills, and to help instructors facilitate digital collaboration effectively. Beyond computer science, expanding research in diverse academic contexts will clarify discipline-specific needs; employing experimental and longitudinal designs—including control or comparison cohorts and longer follow-ups—can strengthen causal claims and assess durability. Addressing digital equity and accessibility (reliable internet, compatible devices, institutional support) is essential for inclusive adoption, and integrating behavioral analytics (activity logs, revision histories, message traces) alongside surveys can provide more objective engagement indicators.

As digital collaboration continues to evolve, CBCTs represent a powerful tool for enhancing student engagement and teamwork in higher education. While challenges remain, structured implementation, institutional support, and continued research can help optimize CBCT integration so that students benefit from interactive, efficient, and accessible learning environments. This study contributes empirical insights and practical recommendations for educators, administrators, and policymakers and, by linking observed patterns with implementation levers, supports evidence-based strategies for strengthening collaborative learning in CS and related disciplines.

Ethical Approval

The research steps were performed under the supervision of the Ethical Committee of L. N. Gumilyov Eurasian National University. This research was conducted for purely scientific purposes with all participating students expressing their written consent to the completion of the research.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Zh.Z. conducted the research, analyzed the data, and drafted the manuscript. A.S. supervised the study, provided conceptual guidance, and revised the manuscript. Zh.Zh. collected and curated data and contributed to editing. Zh.Zh. (Zheniskul) contributed to methodology, validation, and critical revision. A.K. contributed to software, data curation, and manuscript editing. All authors had approved the final version.

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