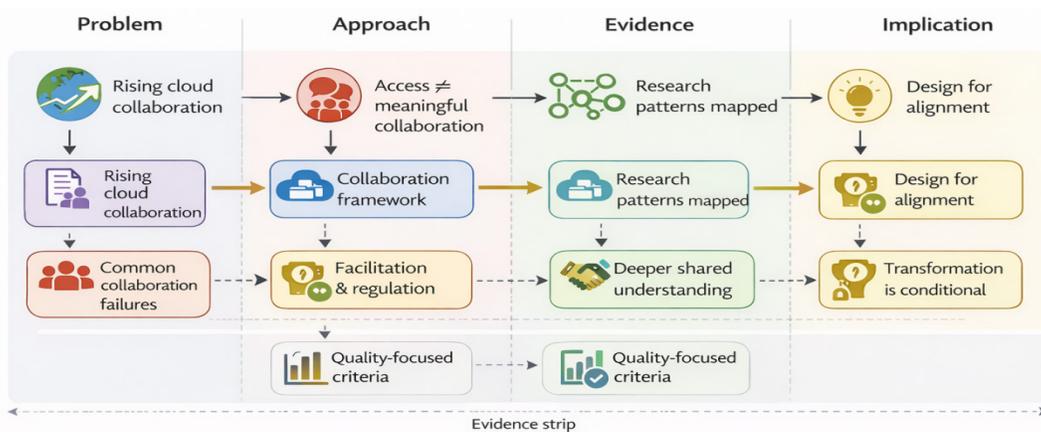


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Graphical abstract

INTRODUCTION

Cloud-based collaborative learning systems are increasingly used for interaction and shared work in online education, yet it remains unclear which forms of collaboration they actually support. Recent syntheses describe expanding interest in cloud-supported group learning while continuing to report challenges in sustaining high-quality participation.^[1, 2] The pressures motivating a renewed collaboration focus are summarized in Fig. (1).

However, shared documents and messaging do not reliably produce productive dialogue or shared understanding. Participation may be uneven, contributions superficial, and coordination fragile. The wider move toward virtual and hybrid work heightens the need for intentional collaboration design rather than tool deployment alone.^[3] This study adopts the premise that **affordance is not learning**.

Building on this premise, this study offers a conceptual framework linking cloud affordances,

task structure, facilitation, and group regulation to interaction quality and knowledge sharing. Options for a modest why-now trend indicator, without turning the argument into a technology survey, are outlined in Tab. (1). The framework treats cloud adoption as an enabling context rather than a guarantee of meaningful collaboration.^[1]

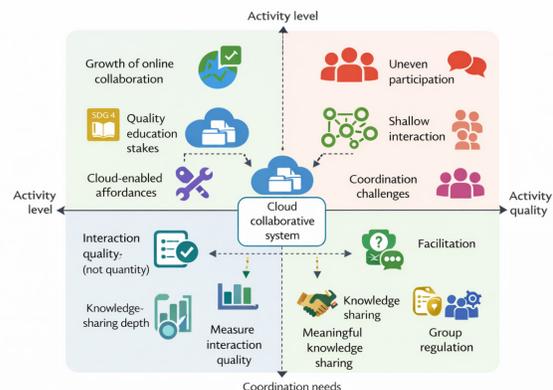


Fig. 1: Drivers of cloud collaborative learning

Table 1: Why-now evidence source options

Source Option	What It Can Show	Why It Fits This Paper
Publication Databases	Growth in research on online collaborative learning and related topics over recent years	Supports a why-now opening without turning the paper into a tool survey
Higher-Education Online Learning Reports	Trends in online learning scale and participation over recent years	Connects the framework to real educational stakes while staying non-technical
Collaborative-Platform Adoption Summaries	Broad adoption or usage trends for cloud-supported shared work in education settings	Motivates the focus on cloud-supported collaboration while avoiding infrastructure detail

COLLABORATIVE LEARNING PROBLEM FRAMING IN ONLINE EDUCATION

Online education increasingly relies on cloud-based shared tools, however access alone seldom yields educationally meaningful collaboration.^[4, 5] High message volume can conceal uneven participation, superficial replies, and weak coordination, so measures of interaction quantity need to be differentiated from interaction quality.^[5] Persistent barriers to knowledge sharing include limited uptake of peers ideas and scarce facilitation that helps groups build on contributions.^[6] Fig. (2) clarifies this shallow-versus-meaningful gap as the central problem addressed here.

Participation and interaction quality pitfalls

Online group work often becomes uneven, with a small subset steering decisions while others contribute

briefly or remain silent. This failure pattern can reflect informal communication dynamics: early talkers set norms, responses cluster around visible contributions, and hesitation grows when disagreement feels socially costly. In such settings, apparent activity may still mask thin mutual awareness and weak turn taking.^[7]

Shallow exchange also occurs when the collaboration modality does not match participants' expertise, for example when fast chat favours confident contributors or shared writing tools demand skills some members lack [8]. Accordingly, prior frameworks treat message counts, replies, and edits as unreliable proxies: frequent posting can remain superficial without explanation, uptake, and coordination toward a shared product.^[7, 8]

Knowledge sharing barriers and facilitation needs

In cloud-based collaborative learning, knowledge sharing can remain superficial because collaboration is more than access to a shared space. It also requires participation in a social learning system with norms, roles, and mutual accountability.^[9] When contributions are optional, uneven, or disconnected, exchange becomes a stream of posts rather than a shared problem-solving process.

Digital coordination and communication tools may reduce the cost of contributing. However, these tools do not ensure ideas are taken up, explained, or integrated.^[10] Facilitation and group regulation are therefore needed to elicit responsiveness, negotiate meaning, and sustain task focus, so knowledge sharing supports co-creation of understanding rather than mere posting.^[9, 11]

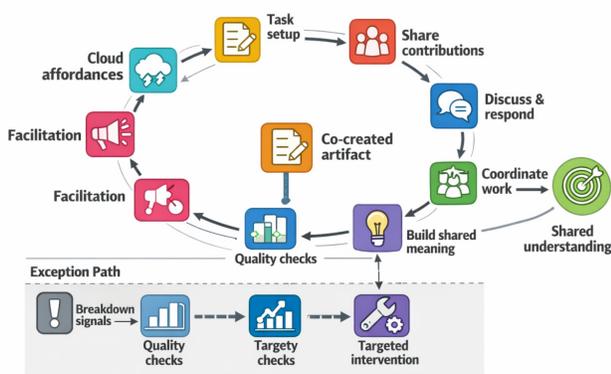


Fig. 2: Shallow interaction versus meaningful knowledge sharing

KEY CONCEPTS AND BOUNDARIES

The framework clarifies and fixes working meanings for cloud-based collaborative learning systems, collaborative learning, interaction quality, knowledge sharing, and facilitation and group regulation, while deliberately omitting cloud infrastructure detail. It differentiates interaction quality from simple activity volume by emphasizing balanced participation, substantive responses, and coordination. Definitions are summarized in Tab. (2). Design constraints are situated in multimedia learning mechanisms^[12] and cognitive load trade-offs in online tasks,^[13, 14] while also noting limits of cognitive load theory in authentic settings.^[14]

Core constructs for collaboration-centred analysis

Collaborative learning is defined here as a purposeful joint activity in which learners work interdependently toward shared academic goals by making ideas visible, responding to peers, and negotiating meaning. It is not treated as a byproduct of co-presence in an online space or of high message volume. By contrast, the construct is differentiated by the quality of contribution, uptake, and coordination that supports learning outcomes.

Facilitation denotes deliberate guidance that frames collaborative work, including task design,

prompts, roles, and feedback intended to keep interaction academically productive. Group regulation refers to how a group plans, monitors, and adapts its joint work, for example by setting norms, checking progress, and repairing breakdowns when coordination fails. Taken together, the analysis prioritizes **learning conditions** rather than specific platforms: cloud systems are considered only to the extent that their affordances shape facilitation and regulation, not as tools to be compared feature by feature.

Working definitions of interaction quality and knowledge sharing

Online collaboration often increases messaging and document edits, yet interaction quantity alone is not a reliable indicator of learning value. In this paper, **interaction quality** clarifies whether a group maintains balanced participation, replies in ways that add explanation or reasoning, and coordinates work so that contributions connect rather than collide. To keep this construct distinct from simple volume, interaction quality is operationalized as a weighted index over these three components, Eq. (1).

$$Q_{int} = w_p B + w_d D + w_c C \quad (1)$$

Knowledge sharing is defined as the purposeful exchange of resources, experiences, or explanations

Table 2: Working definitions of key terms

Term	Working Meaning	Why It Matters Here
Cloud-Based Collaborative Learning Systems	Online learning systems that use cloud-supported shared work and interaction to enable collaboration	Focuses the paper on learning design and interaction, not cloud infrastructure engineering
Collaborative Learning	Learning approach centered on students working together through shared tasks and interaction	Keeps the manuscript grounded in collaborative pedagogy rather than tool features
Interaction Quality	A construct distinct from interaction quantity; tied to participation balance, response depth, and coordination quality	Supports the paper's main distinction between more activity and more meaningful collaboration
Knowledge Sharing	Group exchange that can range from simple posting to explanation, uptake, and joint meaning-making	Defines the key outcome the framework aims to support and interpret
Facilitation And Group Regulation	Support and conditions that guide how groups coordinate and sustain productive collaboration	Explains why cloud access alone does not guarantee meaningful collaboration outcomes

that are visible to peers and are taken up in later group activity, for example by being referenced, questioned, or incorporated into a shared artifact. By contrast, knowledge construction is reserved for a deeper process in which the group jointly builds new understanding by integrating, reconciling, and refining ideas across turns. Knowledge sharing can enable knowledge construction, but information posting that receives no uptake or is not integrated into subsequent work is treated as a failure case and is not counted as construction.

CLOUD-SUPPORTED COLLABORATION FRAMEWORK

The framework treats cloud access as an enabling condition, and its learning value depends on collaborative design, facilitation, and group regulation, with attention to sustainable educational use.^[15] The affordances-to-effects crosswalk clarifies these pathways and cautions that a frequent failure is to equate activity volume with interaction quality, Tab. (3). Optional support features, such

as automated prompts or summaries, should be judged by whether they strengthen interaction quality rather than encourage tool-first adoption.^[16, 17] Fig. (3) summarizes the main affordance-to-effect pathways.

Cloud affordances as collaboration enablers

Cloud-based collaborative learning systems place student work in a shared online environment, keeping resources and contributions available across devices and over time. In this context, a cloud affordance refers to an action the platform readily supports, for example joint editing or discussion around a shared artifact. Such affordances delineate possibilities for collaboration, however they do not by themselves secure learning.

Affordances most directly tied to shared work include co-authoring with revision history, persistent storage that keeps group products and discussions visible, and integrated messaging and notifications that help groups coordinate. Shared links and permission settings can reduce access friction while

Collaborative Learning Blueprint

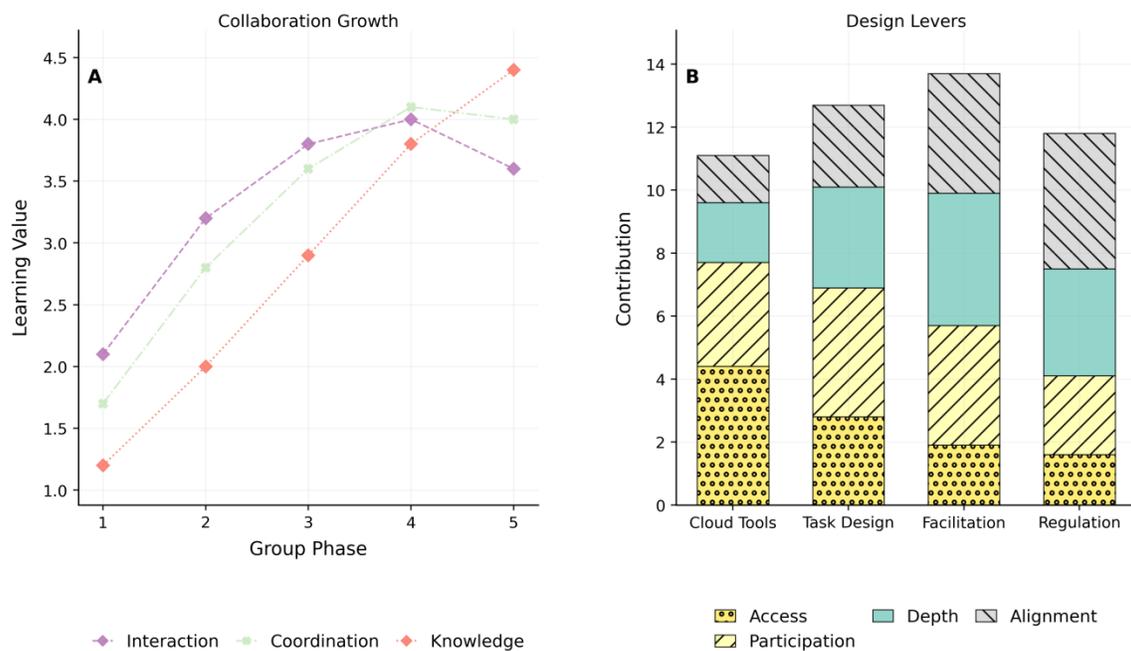


Fig. 3: Collaborative Learning Blueprint

Table 3: Affordances-to-effects crosswalk

Affordance Or Condition	Most Direct Collaboration Effect	Design Note
Cloud access	Enables online collaboration but does not guarantee meaningful collaboration	Needs collaborative design beyond tool access
Cloud-supported shared work	More opportunities to work together and share information	Value depends on task structure and facilitation
Cloud-supported interaction	More visible exchanges among learners	Keep focus on interaction quality, not interaction quantity
Facilitation	More balanced participation and deeper responses	Supports meaningful interaction and knowledge sharing
Group regulation	Better coordination and more sustained group work	Helps move from knowledge sharing toward knowledge construction

also signalling roles and responsibilities within the group.

Even with these supports, interaction can remain superficial when tasks do not require building on peers ideas, or when facilitation and group regulation are weak. enabling not guaranteeing clarifies the central distinction that cloud features create conditions for participation and knowledge sharing, while educational value depends on design and guidance.

Task design, facilitation, and group regulation

Collaborative work in cloud-based environments extends beyond shared access when **task structure** establishes interdependence and an observable sequence of steps. Under these conditions, groups need to coordinate contributions, respond to one another, and periodically revisit shared artifacts. The task flow and key facilitation touchpoints that support participation, coordination, and uptake are summarized in Fig. (4).

Facilitation can then be understood as ongoing noticing and shaping of interaction trajectories, including prompts, revoicing, and timely redirection when discussion stalls.^[18] Facilitation intensity can be tracked as a facilitation rate, defined as the number of facilitation acts per unit time, Eq. (2).

$$F_{rate} = \frac{N_{fac}}{T} \quad (2)$$

When used diagnostically, a higher rate is not inherently better, but it can indicate moments when

additional regulation may be needed to keep the group progressing through the task.

Regulation is also enacted through structured feedback that makes the emerging knowledge structure visible, for example by requiring explanation, linking claims to evidence, and capturing decisions in shared representations.^[19] Taken together, facilitation and feedback operate as complementary regulation mechanisms that can convert cloud affordances into sustained collaborative work and deeper knowledge sharing.^[18, 19]

Outcome pathways from interaction to knowledge construction

Interaction quality reflects how effectively learners participate, respond, and coordinate in cloud-supported shared work. However, it is educationally consequential only when it enables knowledge sharing. Knowledge sharing, in turn, supports knowledge construction when peers explain ideas, take up one another's contributions, and revise a shared product. A **reinforcing feedback loop** can arise when the evolving product makes goals and norms clearer, which then supports stronger interaction in later cycles.

A compact pathway represents knowledge construction as a propensity shaped by interaction quality, facilitation rate, and task structure in Eq. (3).

$$K_{const} = \frac{1}{1 + \exp(-(\beta_0 + \beta_1 Q_{int} + \beta_2 F_{rate} + \beta_3 S_{task}))} \quad (3)$$

Higher q-value increases the likelihood that sharing moves beyond posting toward joint meaning-making.

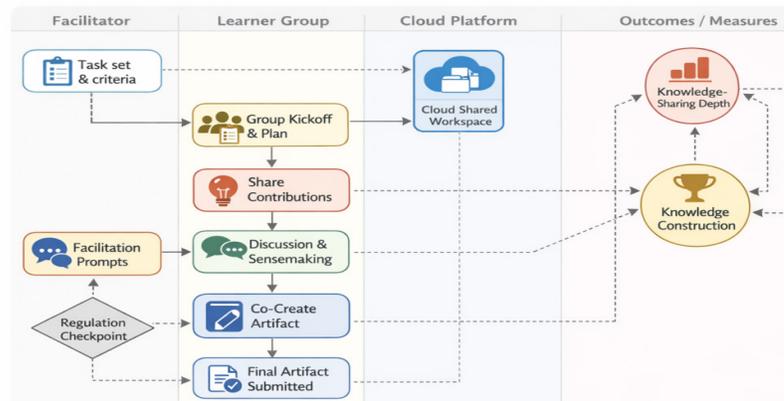


Fig. 4: Task flow with facilitation and regulation

Facilitation helps sustain focus and more equitable participation, while task structure makes epistemic work necessary. As construction strengthens, coordination can become easier and feed back into q-value, supporting more productive sharing in subsequent cycles.

APPLYING THE FRAMEWORK TO SYSTEM AND PEDAGOGY PATTERNS

Interpreting recognizable cloud-supported collaboration patterns requires identifying which framework elements are most active at a given time. Tab. (4). clarifies this taxonomy by linking sharing, discussion, coordination, and knowledge construction to specific combinations of cloud affordances, task structure, facilitation, and group regulation. Taken together, the mapping supports design diagnosis by indicating that progress from posting to joint meaning-making depends on facilitation and regulation, rather than on access alone.

Representative cloud-supported collaboration patterns

Cloud-based collaborative learning designs often recur as identifiable patterns that connect platform affordances with participation, coordination, and knowledge sharing. Fig. (5) situates these patterns within a group learning cycle in which activity can move from simple sharing toward joint knowledge building, clarifying that early exchange typically requires structuring and facilitation to develop into productive interaction.

Within this taxonomy, one pattern is **lightweight scaffolding** via signalling and annotation, where learners mark relevance, questions, or agreement directly on shared artifacts to reduce coordination cost and invite responses.^[20] A second pattern uses structured discussion prompts linked to a shared workspace so contributions remain visible and revisit able over time, supporting more balanced turn taking and clearer uptake of ideas.^[20]

Table 4: Patterns mapped to framework elements

Collaboration Pattern	Framework Elements in Focus	What It Supports
Sharing	Cloud-enabled affordances, knowledge sharing	Posting and exchanging ideas or resources
Discussion	Task structure, facilitation, interaction quality	Responding with depth, building on other contributions
Coordination	Group regulation, interaction quality	Organizing roles, timing, and shared work
Knowledge Construction	Knowledge sharing, facilitation, group regulation	Joint meaning-making beyond simple posting

A third pattern introduces automated discussion support, such as proposing prompts or summaries. This can lower initiation barriers, however it also raises adoption and interpretability concerns.^[21, 22] To evaluate knowledge-sharing depth, coded exchange levels can be aggregated rather than counting posts, aligning assessment with the progression from sharing to knowledge building, Eq. (4).

$$D_{share} = \sum_{k=0}^K \alpha_k \frac{n_k}{N} \quad (4)$$

Taken together, this framing differentiates learning gains attributable to scaffolds from risks associated with automated responses.^[20, 21]

Using the framework to diagnose and improve collaboration

Effective application of the proposed framework starts by diagnosing where collaboration fails in an online activity, rather than presuming that shared cloud tools will in themselves produce learning. Tab. (5) clarifies this diagnostic step by summarizing common questions as observable signals with corresponding design moves.

Several breakdown patterns can be differentiated. Uneven participation indicates a need for facilitation and group regulation, as well as tasks that create interdependence so that each contribution is consequential. High message volume with little explanation suggests that **interaction quality**

requires support, for example through prompts that elicit reasons, responses, and coordination. When knowledge sharing remains limited to posting information, activities can be structured to shift toward discussion, joint planning, and deeper knowledge building. When cloud access is treated as the solution, design should instead link platform affordances explicitly to collaborative goals and facilitation routines.

DISCUSSION AND IMPLICATIONS

The framework shifts attention from cloud access to conditions for meaningful collaborative learning, differentiating task structure, facilitation, and group regulation. Design implications appear in Tab. (6). By contrast with assumptions of benefit, the table foregrounds common failure modes and responses and treats knowledge sharing and interaction quality as outcomes that require support rather than defaults.

Implications for research and learning design

The framework differentiates cloud access and simple activity counts from **interaction quality** and the processes through which exchange becomes knowledge sharing. Frequent posting may still be shallow, however balanced participation, responsive dialogue, and coordinated work are more consistent with meaningful collaboration.

Table 5: Diagnostic questions and design moves

Diagnostic Question	What To Look For	Design Move
Is participation uneven?	A few voices dominate; many students stay quiet	Add facilitation and group regulation, redesign task structure to require shared work
Is interaction only high in quantity?	Many posts or messages but little response depth	Refocus on interaction quality (response depth, coordination quality), add prompts that require explanation and uptake
Is knowledge sharing staying shallow?	Posting information without moving toward joint meaning-making	Design activities that move from sharing toward discussion, coordination, and deeper knowledge building
Is cloud access being treated as the solution?	Tool use is present but meaningful collaboration is not improving	Use the framework: link cloud affordances with collaborative design and facilitation, avoid tool-centered assumptions

Table 6: Failure modes and recommended responses

Failure Mode	What It Looks Like	Recommended Response
Uneven Participation	Participation concentrated in a few students	Add facilitation and group regulation; use collaborative task structure to support balanced participation
Shallow Interaction	High activity but low interaction quality (quantity without meaningful exchange)	Focus on interaction quality; use facilitation to move exchange toward deeper discussion and knowledge sharing
Posting Without Building	Knowledge sharing stays at simple posting instead of joint meaning-making	Use facilitation to shift from sharing to explanation, uptake, and deeper knowledge construction
Tool-First Framing	Cloud access treated as if it guarantees meaningful collaboration	Recenter design on the collaborative learning problem; link cloud affordances to task structure, facilitation, and regulation rather than tools alone
Overstated Transformation	Broad claims that cloud systems transform learning without clear limits	Use careful transformation language; state scope boundaries and emphasize conditions needed for meaningful interaction and knowledge sharing

For research, this perspective clarifies that evaluations should trace how affordances, task structure, facilitation, and group regulation shape participation patterns and the depth of contributions over time, rather than treating the platform as the intervention.

For learning design, the framework elaborates the value of aligning cloud tools with collaborative

scripts and shared artifacts that keep ideas visible and revisable, and pairing these with facilitation moves such as prompts, roles, and norms for uptake. Taken together, design decisions can be judged by whether they strengthen interaction quality and support a progression from sharing to joint meaning-making.

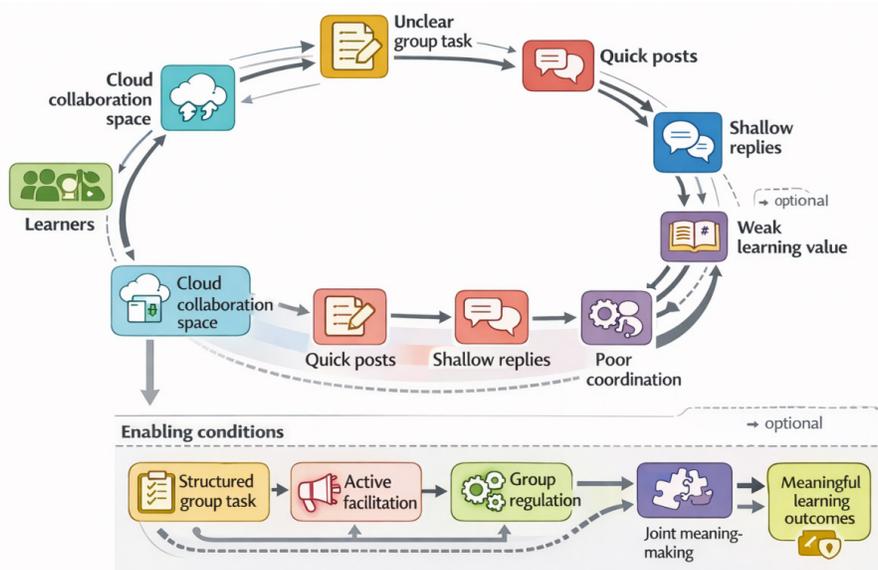


Fig. 5: Boundaries for responsible transformation claims

Limits and responsible transformation claims

Transformation in cloud-supported collaboration should be claimed only when facilitation and group regulation improve interaction quality and deepen knowledge sharing, not when they merely increase access or posting. Fig. (6) situates this limit.

Thus, transformation is a constrained claim, bounded by demonstrated interaction quality and knowledge sharing depth Eq. (5). The bounding form

$$T_{claim} = \min\{1, \gamma Q_{int} D_{share}\} \quad (5)$$

supports careful language about improved conditions rather than guaranteed outcomes.

CONCLUSION

This study proposes a collaboration-centered framework that situates cloud-based collaborative learning systems as supporting meaningful interaction and knowledge sharing only when platform affordances align with task structure, facilitation, and group regulation. By contrast, when these elements are not well aligned, activity volume can increase while interaction quality remains low, which clarifies a common failure regime in practice. The framework also differentiates knowledge sharing from deeper knowledge construction, which depends on uptake, explanation, and coordinated work on shared artifacts. Taken together, the model supports realistic design and evaluation. Transformation is therefore best understood as improved conditions for sustained co-creation, rather than as an automatic effect of cloud access.

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