Comparing students' social knowledge construction in the Metaverse-based and chat-based collaborative learning

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Abstract: This study compares students' social knowledge construction (SKC) in an immersive Metaverse platform and an asynchronous chat platform within a cross-cultural collaborative task on the Sustainable Development Goals (SDGs). Guided by social constructivist theory and the Cognitive Affective Model of Immersive Learning (CAMIL), interaction data from 72 undergraduate students were analyzed using a revised Interaction Analysis Model (IAM) and Epistemic Network Analysis (ENA). Results show that Metaverse-based sessions promoted higher frequencies of information sharing (KC1) and socially oriented discourse (KC6), whereas chat-based interactions supported more negotiation of meaning (KC3) and application of knowledge (KC5). ENA visualizations revealed stronger epistemic connectivity among advanced discourse moves in chat-based environments. These findings suggest aligning platform affordances with pedagogical goals, leveraging immersive tools for engagement and rapport, and asynchronous tools for deeper elaboration, while reframing social talk as a relational bridge in cross-cultural collaboration.

Keywords: Collaborative learning, chat, immersive learning, social knowledge construction, metaverse,

1. Introduction

Immersive technologies such as the Metaverse enable real-time, embodied, and spatially rich interaction, offering unique affordances such as avatar-mediated presence, multimodal cues, and spatial navigation that can deepen engagement and support situated, constructivist learning (Dede, 2009; Mystakidis, 2022). While prior research highlights the Metaverse's potential for collaborative problem-solving (Radianti et al., 2020), little empirical work has examined *how* learners construct knowledge socially in such environments, and how these processes differ from those in asynchronous, text-based settings.

Social knowledge construction (SKC), grounded in social constructivist theory (Vygotsky, 1978; Stahl, 2006), involves negotiation, questioning, and mutual regulation to advance shared understanding, aligning with the principle of collective cognitive responsibility (Scardamalia & Bereiter, 2010). In immersive contexts, SKC combines verbal, spatial, and multimodal communication, yet its interactional patterns and underlying mechanisms remain underexplored, particularly the role of technological affordances in shaping epistemic engagement. Epistemic engagement here refers to sustained participation in higher-order processes such as questioning, elaborating, and synthesizing.

This study compares two deliberately sequenced environments within the same collaborative learning design: synchronous, voice-based sessions in the Metaverse

(Gather Town) for idea generation and embodied discussion, and asynchronous, text-based communication in LINE for refinement and elaboration. Beyond modality differences, the Metaverse affords spatial presence and avatar embodiment theorized to foster rapport and immediacy (Makransky & Petersen, 2021), whereas LINE's persistent textual format may encourage reflective contributions but lacks embodied cues. Guided by the Cognitive Affective Model of Immersive Learning (CAMIL) and affordance theory, we conceptualize technological features as mediators interacting with task purpose, temporal structure, and pedagogical intent to shape SKC outcomes.

This study addresses the following research questions:

(1) What are the structural characteristics of student interaction networks in Metaverse-based collaborative learning environments compared to the conventional interaction through real-time asynchronous chat?

(2) What patterns of social knowledge construction behaviors emerge among students during collaborative tasks in the Metaverse compared to the conventional interaction through real-time chat?

2. Literature Review

2.1. Social knowledge construction in online collaborative learning

Social knowledge construction (SKC) refers to learners' collaborative negotiation, conflict resolution, and joint meaning-making through discourse (Gunawardena et al., 1997). Grounded in Vygotsky's (1978) social constructivist theory, SKC frames learning as a dialogic process in which higher-order thinking first develops socially before becoming internalized (Stahl, 2006). The Interaction Analysis Model (IAM) (Gunawardena et al., 1997) categorizes SKC into five phases: information sharing (KC1), cognitive dissonance (KC2), negotiation of meaning (KC3), synthesis testing (KC4), and application of new knowledge (KC5).

Although IAM is widely applied in asynchronous text-based settings, its use in synchronous, multimodal, and immersive contexts remains limited. Existing work often focuses on cognitive or linguistic outcomes (Lee & Bonk, 2016) without examining how technological affordances such as modality, persistence, and spatial representation mediate both social dynamics and epistemic engagement. Given the shift toward multimodal, distributed learning environments, SKC analysis must integrate these affordance-related mechanisms, particularly in contexts where tools are intentionally assigned for distinct phases of collaboration.

2.2. Metaverse-based collaborative learning

The Metaverse is a digitally immersive environment enabling embodied, spatially aware, and interactive learning spaces (Mystakidis, 2022). In education, it supports enhanced presence, co-location, identity exploration, and multimodal expression (Dede, 2009). Its unique affordances, proximity-based audio, avatar-mediated interaction, and manipulable artifacts can foster immediacy, rapport, and co-construction of knowledge (Park & Kim, 2022).

However, most studies in this area focus on usability, engagement, or motivation (Radianti et al., 2020), leaving a gap in understanding the epistemic processes within immersive environments. Moreover, when the Metaverse is deliberately positioned for synchronous ideation and LINE for asynchronous refinement, as observed in this study, SKC differences may stem from the interaction of affordances, temporal structure, and pedagogical purpose, not from modality alone. This highlights the need to disentangle how real-time spatial dynamics and asynchronous persistence shape the mechanisms of SKC.

3. Methodology

3.1. Participants

The study involved 72 undergraduate students (aged 19 to 24) from two universities in Taiwan and Indonesia who participated in a Cross-Cultural Communication course. All had basic digital literacy but no prior structured intercultural online discussion experience. They were

placed into 15 mixed-nationality groups of 5 to 6 members, each led by a facilitator. Taiwanese students joined in-person on campus, while Indonesian students participated remotely from campus or home. Gather Town was used exclusively for synchronous, avatar-mediated sessions; LINE was used solely for asynchronous follow-up, ensuring differences reflected each platform's affordances and temporal structure.

3.2. The instructional design of the study

The three-week SDG-themed project was deliberately sequenced to match platform strengths. Gather Town supported synchronous video/audio and spatial interaction for idea generation, while LINE enabled asynchronous coordination, file sharing, and refinement. Following a social constructivist multi-layered framework, students first held intragroup discussions in Gather Town, then participated in intergroup feedback sessions, and finally co-created an infographic. The instructor provided ongoing scaffolding, technical support, and guided summarization. Figure 1 shows the task flow and platform transitions.
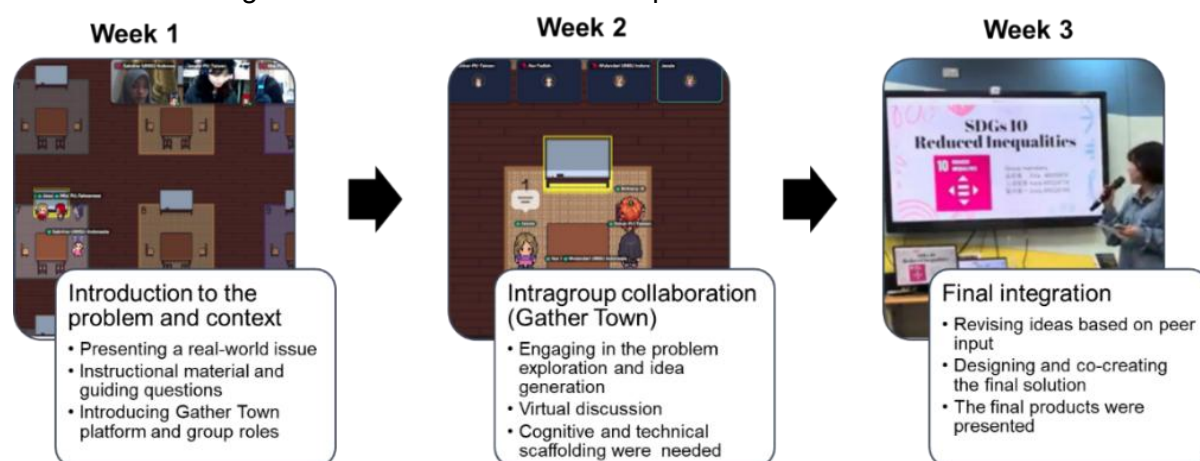

Figure 1. The instructional design of the study

3.3. Data collection and analysis

To investigate the dynamics of social knowledge construction in the Metaverse, this study analyzed social knowledge construction (SKC) using content analysis supported by Epistemic Network Analysis (ENA) to capture both the structural properties and epistemic quality of interactions. Data came from two sources: (1) 1,312 transcribed utterances from Gather Town (synchronous, embodied negotiation) and (2) 784 cleaned LINE messages (asynchronous coordination and refinement). All entries were time-stamped and sequenced for temporal modeling, ensuring consistency across platforms.

Discourse was coded using a modified Interaction Analysis Model (Gunawardena et al., 1997), retaining KC1–KC5 and adding KC6 for off-task/relational exchanges that support group cohesion in cross-cultural contexts. Two trained coders reached κ = 0.81 (Fleiss, 1981); disagreements were resolved through discussion to maintain theoretical alignment.

ENA (Shaffer et al., 2016) was applied via the ENA Web Tool (https://www.epistemicnetwork.org) to model co-occurrence and temporal proximity of coded moves. Gather Town and LINE datasets were chronologically merged so that temporally adjacent utterances, regardless of platform, were analyzed in sequence. Each unit was treated as a node, segmented by turn or message sender. Network graphs visualize co-occurrence strength (edge thickness) and epistemic focus (centroid position), allowing direct comparison of patterns across the two environments.

4. Findings and Discussion

4.1. What are the structural characteristics of student interaction networks in Metaverse-based collaborative learning environments compared to the conventional interaction through real-time asynchronous chat?

The two platforms were intentionally assigned distinct roles: Gather Town for synchronous, embodied discussion, and LINE for asynchronous, text-based refinement. Differences in discourse patterns thus reflect not only platform affordances but also task sequencing and temporal structure.

Off-topic or socially oriented talk (KC6) dominated both contexts, 63.26% in Gather Town and 58.63% in LINE. While not directly epistemic, KC6 served relational purposes, fostering rapport and easing intercultural interaction functions supported in prior work (Chamola et al., 2024). The slightly higher KC6 in Gather Town may relate to avatar presence and multimodal cues enhancing social bonding (Lin et al., 2022), whereas in LINE, KC6 more often transitioned to negotiation (KC3), suggesting reflective scaffolding. As social presence was not directly measured, these interpretations are inferential.

Information sharing (KC1) was higher in Gather Town (23.06%) than LINE (15.26%), likely due to immediacy of verbal exchanges and use of shared artifacts, but much remained surface-level, consistent with findings that immersive contexts require scaffolding for deeper reasoning (Parong & Mayer, 2018). Conversely, KC3 was notably higher in LINE (18.47% vs. 2.29%), aligning with literature on asynchronous environments enabling reflection and deliberate response (Lee & Bonk, 2016).

Both settings showed low synthesis (KC4) and application (KC5), with slightly higher KC5 in LINE (6.83% vs. 2.76%), indicating a common challenge in advancing toward integrative reasoning without explicit facilitation (Barana et al., 2023). Discovery of dissonance (KC2) was rare in both (8.04% in Gather Town, 0.80% in LINE), reflecting limited peer-challenging again consistent with studies showing students often avoid critique unless prompted (Yoo et al., 2024).

These findings indicate that platform affordances and design intentions jointly shaped interaction patterns: Gather Town promoted immediacy and rapport, while LINE supported more reflective negotiation and application.

Table 1. *The structural characteristics of students' interaction networks across the two tools*

	Metaverse-based interaction		Conventional real-time chat interaction		Total
	N	%	N	%	
KC1	301	23.06	38	15.26	339
KC2	105	8.04	2	0.80	107
KC3	30	2.29	46	18.47	76
KC4	7	0.54	0	0	7
KC5	36	2.76	17	6.83	53
KC6	826	63.26	146	58.63	972
Total	1305	100	249	100	1554

4.2. What patterns of social knowledge construction behaviors emerge among students during collaborative tasks in the Metaverse compared to the conventional interaction through real-time chat?

ENA visualizations (Figure 2) compare the Metaverse (red) and LINE (blue) networks. Although LINE enables near real-time messaging, replies were often delayed by hours; thus, it is treated as asynchronous. The maps show both the frequency of epistemic moves and the transitions between them.

In the Metaverse, the strongest link was between KC1 (Sharing/comparing information) and KC6 (Social/off-topic talk) at 0.87, indicating frequent alternation between task-related and informal exchanges. Affordances such as avatar presence, proximity-based audio, and spatial navigation likely supported this blending of social and task talk. However, transitions from KC6 to higher-order moves, namely KC5 (Application) at 0.13, KC2 (Dissonance discovery) at 0.28, KC3 (Co-construction), and KC4 (Synthesis), were minimal, echoing findings that immersive environments encourage engagement but require structured facilitation for deeper reasoning (Lin et al., 2022).

LINE networks showed stronger links between advanced moves, particularly between KC6 and KC3 (0.39) as well as between KC1 and KC6 (0.38). In these instances, social talk often served as a bridge to negotiation of meaning, benefiting from asynchronous conditions that allow planning, reflection, and elaboration, consistent with Gagliani et al. (2025).

Statistical results reinforce this: a two-sample t-test on ENA centroid X-axis values (co-construction weight) found Gather Town (M = -0.25, SD = 0.12, N = 15) significantly lower than LINE (M = 0.29, SD = 0.45, N = 13), t(13.40) = -4.18, p < .001, d = 1.69. This confirms that asynchronous chat supported more frequent and stronger KC3, while Gather Town emphasized KC1 and KC6, similar to patterns reported by Li et al. (2024).

KC4 and KC2 remained low in both contexts; the Metaverse showed slightly more idea divergence, while LINE had more KC5, indicating greater convergence and application. These patterns align with Barana et al. (2023), suggesting that without scaffolding, immersive tools may stall in exploratory phases, whereas asynchronous tools more effectively promote integrative reasoning.
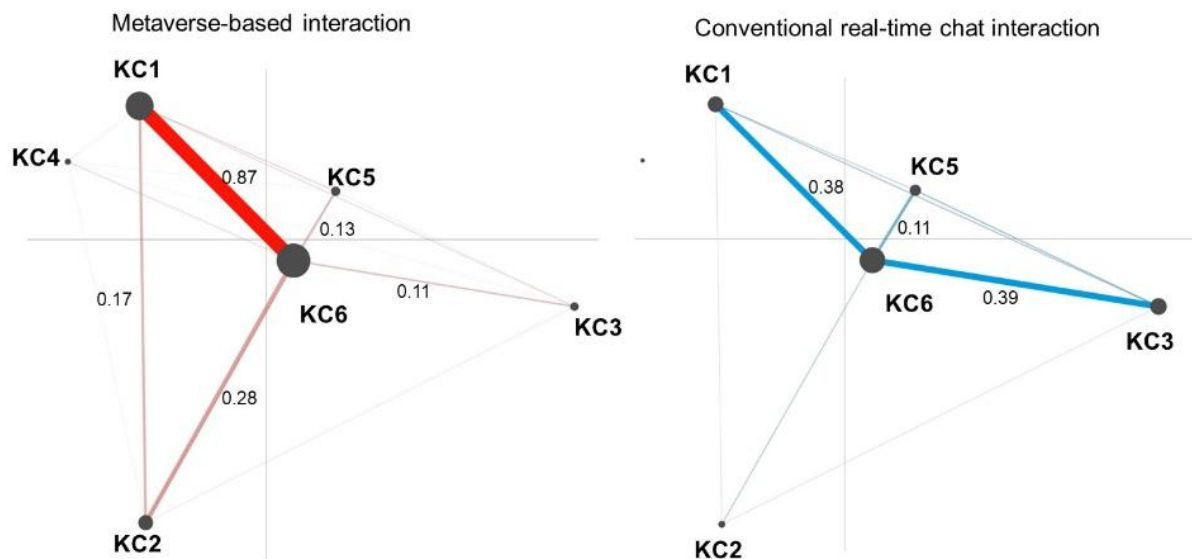

Figure 2. The social knowledge construction of students across two tools

5.   Conclusion

This study compared social knowledge construction (SKC) in an immersive Metaverse environment (Gather Town) and an asynchronous chat platform (LINE) within the same cross-cultural collaborative design. Using content analysis and Epistemic Network Analysis (ENA), results showed that Gather Town interactions were dominated by information sharing (KC1) and socially oriented talk (KC6), whereas LINE more frequently supported negotiation of meaning (KC3) and application of knowledge (KC5). Interpreted in light of the intentional design synchronous embodied discussion in the Metaverse and asynchronous refinement in LINE these differences reflect the combined influence of platform affordances, task sequencing, and temporal structure. Immersive tools can enhance engagement and rapport but need structured scaffolding to promote higher-order reasoning; asynchronous tools better enable reflection and elaboration. Socially oriented talk should be recognized as a relational bridge in cross-cultural collaboration. Limitations include the modest sample size, short duration, and context-specific scope. Future research should involve more diverse cohorts, extended interventions, varied platforms, and targeted scaffolding strategies, including AI-assisted prompts. Overall, findings emphasize that epistemic engagement emerges from the interaction of technological affordances and socio-relational dynamics, and that channeling social exchanges into knowledge building is critical for effective collaborative learning.

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