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Exploring Shared Agency in an Intelligent Immersive Learning Environment for Collaborative Writing

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Abstract: An increasing number of studies on AI-student collaboration highlight the importance of learner agency in the Generative AI (GenAI)-powered learning environment. However, limited research has examined how student-AI shared agency can be assessed, and it remains unclear whether individual interaction with AI agents or peer collaboration with AI agents is more effective in developing such agency. This study explores second language (L2) students' shared agency within an intelligent immersive learning environment for writing. Using WriteCube, a self-developed AR- and AI-enabled writing system, 75 Primary 4 students from two classes in Singapore completed picture-based composition tasks under individual-AI and pair-AI collaboration conditions. Findings revealed no significant performance difference between groups, suggesting a trade-off between interactional richness and task efficiency. Regression results indicated that interaction quality, rather than frequency or language proficiency, positively predicted shared agency, particularly in ensuring equity. The study offers implications for assessing and enhancing learner agency in GenAI-supported L2 classrooms.

Introduction

Agency has become a central concern in discussion on Generative AI (GenAI) integration in teaching and learning (Darvishi et al., 2024). The notion of agency has been typically defined as the learner's capacity to act intentionally and exert control over their learning (Bandura, 2002). While from the sociocultural perspective, agency is not merely a personal trait but also an inherently collective phenomenon, shaped by social, cultural, and contexts (Eteläpelto et al., 2013), and fundamentally emerging as the result of inter-subjective processes. As the use of GenAI increasingly destabilizes boundaries between humans and technology, it becomes critical to examine learner agency by considering how they navigate, critique, and shape learning experiences with GenAI (Code, 2025). This study seeks to examine shared agency between students and AI agents, building on the concept of collective human agency in studies of computer-supported collaborative learning (Scardamalia & Bereiter, 2014; Zhang et al., 2021), while also incorporating considerations of ethical engagement and critical awareness (Ralston, 2023). Student-AI shared agency, in this study, is conceptualized as the emergent and dynamic capacity of students to co-act with AI agents. There remains a lack of research on how shared agency can be assessed (Code, 2025). Moreover, it is still unclear whether individual interaction with AI agents or peer collaboration with AI agents is more effective in developing Student-AI shared agency.

To address this gap, the present study was proposed and conducted based on WriteCube, a self-designed and developed writing system for Chinese as a second language (L2) learning. The system brings students into immersive augmented reality (AR) scenarios, empowered by AI agents. AR and AI together offer complementary strengths for designing L2 writing environments (Wen et al., 2025). While AI support often remains decontextualized, lacking the authentic and multimodal cues needed to ground language use in real-world contexts, AR technologies provide authentic, multisensory, and context-rich environments that situate writing tasks in meaningful scenarios, enhance motivation, and reduce language anxiety (Yang et al., 2023). The system was implemented in two Primary 4 Chinese language classes from a school in Singapore. This study aimed to deepen understanding and empirically examine agency in the GenAI-powered learning environments. The findings sought to provide design and implementation suggestions for using such learning systems in classrooms.

Theoretical foundations

Code developed the Agency for Learning Framework to measure agency in learning context by considering both individual and environmental influences on learners' ability to act (Code, 2020). As the agency of technology is acknowledged, technology does not only play a role in mediating learner agency. Code further proposed the updated framework about the Postdigital Learner Agency, "equipping leaners to navigate, critique, and shape the systems mediating their educational experiences" (Code, 2025, p.338). In this perspective, agency extends beyond individual action to include collective and relational dimensions. Collective agency emphasizes collaboration, co-regulation, and shared goals, fostering mutual understanding and problem-solving (Lipponen & Kumpulainen

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2011), while relational agency emphasizes the dynamic and contextual nature of agency shaped through interactions with both human and non-human actors (Siles et al., 2024). Building on this perspective, the present study proposes student-AI shared agency, highlighting the dynamic and contextual nature of agency emerging through interactions between learners and AI systems.

The integration of GenAI as a partner broadens the scope of collaborative L2 writing. Existing studies have examined how students individually use GenAI in collaborative writing contexts (e.g., Kim et al., 2025), as well as how human peers work with GenAI to mitigate limitations in language proficiency that may hinder effective interaction with AI agents (e.g., Michel et al., 2025). Human peers bring contextual sensitivity, affective support, and stronger benefits for long-term retention (Yang et al., 2023). Despite growing research on AI-assisted writing, little is known about how factors such as students' language proficiency, engagement level, and collaboration mode (individual-AI vs. human peer collaboration) shape student-AI shared agency in L2 writing. Addressing this gap is essential for understanding how human and AI collaborators jointly contribute to the development of shared agency in AI-supported writing environments. The following research questions guide this pilot study.

RQ1: Do individual and pair writing modes differentially impact students' writing performance and student-AI shared agency development?

RQ2: What factors are associated with student-AI shared agency development in the intelligent immersive learning environment?

Research design

Participants and setting

The study involved 75 Primary 4 students from two intact classes in a Singapore primary school, taught by the same Chinese language teacher (15 years' experience). The two classes were selected because they followed the same curriculum and were taught by the same teacher, helping hold instructional conditions constant while implementing different collaboration modes. Class A worked in the individual-AI condition (N = 37). Class B worked in the pair-AI condition (N = 38), with pairs randomly assigned within the class.

Procedure

Students completed a 45-minute technical familiarization session followed by a 60-minute WriteCube activity. WriteCube renders task images as AR scenes and supports composing through two interaction phases: (1) a touchpoint phase for fine-grained description via short dialogues and role-play, and (2) a chatroom phase for developing coherent paragraphs when additional support is needed. An AI agent prompts idea elaboration, recommends expressions, and provides feedback. In a final stage, the AI generates a draft composition from students' inputs and students iteratively revise and complete a self-reflection checklist.

Measures

(a) Writing performance: pre- and post-writing compositions were scored on the school's 20-point rubric by two trained raters; final scores were averaged. We tested condition differences via one-way ANCOVA with pre-writing as covariate. (b) Shared agency: a post-survey adapted from a collective agency scale (Zhang et al., 2022) and extended with items reflecting reflective/ethical engagement with AI (Ralston, 2023). Exploratory factor analysis (Varimax) yielded three indices after removing two cross-loading items: ***autonomy perception*** (2 items, α = .63, e.g., I try to think of my own/my group sentences and ideas before reading what the AI writes.), ***collective efficacy*** (7 items, α = .87, e.g., I believe I/my group can work together with AI to solve writing problems.), ***ensuring equity*** (5 items, α = .86, e.g., Before starting the writing, I think about what I/my group want to write by myself/ourselves and where I/we want the AI to help).Condition effects were examined via MANOVA.

Process indicators and analysis:

Dialogue logs captured full student-AI exchanges. We computed (i) number of turns, (ii) average turn length, and (iii) number of 'good words' (teacher-endorsed descriptive keywords recorded in system logs) as a proxy of interaction quality. Multiple regressions examined associations between shared-agency indices and pre-writing scores plus process indicators.

Findings

No significant differences in either writing performance or shared agency

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ANCOVA showed no significant difference in post-writing scores between the individual-AI and pair-AI conditions, $F(1, 58) = 3.65$, $p = .061$, partial $\eta^2 = .059$, although the individual-AI group showed a slightly higher adjusted mean (12.13 vs. 10.46). Process logs indicated that students in the individual-AI condition produced more dialogue turns (38.45 vs. 26.71), whereas turns in the pair-AI condition were slightly longer on average (9.26 vs. 8.48 words); the number of "good words/keywords" was comparable across groups (Table 1).

Box's test of equality of covariance matrices was examined ($p > 0.05$), indicating that the equality of covariance matrices was met. MANOVA further suggested no significant overall effect of condition on the three shared-agency dimensions, Wilks' $\Lambda = .958$, $F(3, 54) = 0.80$, $p = .502$, partial $\eta^2 = .042$. Follow-up univariate tests were also nonsignificant for autonomy perception, collective efficacy, and ensuring equality (Table 2), with ensuring equality descriptively higher in the pair-AI group.

Table 1
Descriptive Analysis of Student-AI Dialogues

Explanatory variable	Mean (SD)	
	Individual -AI	Pair-AI
Number of turns	38.45 (9.21)	26.71 (11.49)
Length of each turn	8.48 (4.73)	9.26 (6.67)
Number of good words	3.30 (1.78)	3.06 (1.86)

Table 2
MANOVA Summary of Student-AI Shared Agency

Dependent Variable	$F(1, 56)$	p	Partial η^2	Mean (SD)	
				Individual -AI	Pair -AI
Autonomy perception	0.09	.769	.002	3.60 (.19)	3.67 (.17)
Collective efficacy	0.50	.482	.009	3.87 (.18)	3.70 (.16)
Ensuring equity	0.42	.521	.007	3.45 (.20)	3.63 (.18)

Factors associated with student-AI shared agency development

Variables showed low intercorrelations and were retained for regression analyses. Separate regressions indicated that only the model predicting ensuring equality reached significance. Specifically, the number of good words/keywords positively predicted ensuring equality ($b = .191$, $p < .05$), whereas the number of dialogue turns negatively predicted it ($b = -.022$, $p < .05$), explaining 18% of variance ($R^2 = .180$). Models for autonomy perception and collective efficacy were not significant.

Qualitative inspection of dialogue logs suggests that many high-frequency exchanges reflected prompt-following behavior, where students adopted AI suggestions with limited elaboration. For example, students often directly reused AI-provided expressions such as "眉头紧皱" in expanded descriptions (e.g., "丽丽低着头，眼睛看着桌子，眉头紧皱"), or inserted idiomatic phrases like "心里像吃了蜜糖一样甜" with minimal modification. In contrast, episodes associated with higher perceived equality involved meaning clarification and integration, such as a student asking "尽管是什么意思？" and then applying it appropriately in the next sentence. Some students also treated the AI as a linguistic resource, requesting support (e.g., "你能给我一些好词好句吗？") before integrating the expressions into their narratives. Notably, explicit critique of AI suggestions was rarely observed.

Discussion

The absence of significant performance differences between the individual-AI and pair-AI groups suggest a potential trade-off between interactional richness and task efficiency. Students working individually interacted with the AI more frequently and maintained continuous task engagement, which may explain their slightly higher writing scores. In contrast, pair-AI collaboration involved fewer but longer dialogue turns, reflecting additional peer negotiation. This pattern aligns with research suggesting that early-stage L2 writers often move from imitative uptake toward deeper linguistic integration as they internalize scaffolding (Guirao et al., 2015). While peer collaboration may promote reflection and evaluation, such benefits may not immediately appear in short-term performance measures.

Regression results further indicated that interaction quality rather than interaction frequency predicted shared agency, particularly in the dimension of ensuring equality. Students who incorporated more meaningful expressions into their dialogues reported stronger perceptions of balanced collaboration with AI, whereas more frequent but surface-level exchanges were associated with lower perceived equality. Interestingly, language

proficiency did not significantly predict shared agency. This suggests that, compared with traditional peer collaborative writing where proficiency often shapes participation (Susanti et al., 2020), AI-supported environments may reduce participation disparities and allow lower-proficiency learners to engage more actively.

Overall, these findings highlight that students' perception of shared agency depends less on how often they interact with AI and more on how meaningfully they integrate AI suggestions into their own ideas. Future research should further explore instructional strategies that encourage deeper interaction with AI, including prompting students to question, reinterpret, or critique AI-generated suggestions.

Conclusion

This exploratory study examined student-AI shared agency in an intelligent immersive L2 writing environment. The findings suggest that individual-AI and pair-AI collaboration produced comparable writing outcomes and similar levels of shared agency, while interaction quality emerged as a key factor associated with students' perceptions of equal collaboration with AI. Several limitations should be acknowledged. The relatively small sample size and short intervention period may have limited the statistical power to detect subtle differences between conditions. Future studies with larger samples and longitudinal designs are needed to examine longer-term effects on language development and agency formation. In addition, while qualitative observations helped interpret quantitative patterns, a more systematic analysis of student-AI interaction processes could further illuminate how shared agency develops over time. Despite these limitations, the study provides an initial empirical perspective on assessing shared agency in AI-supported learning environments and highlights the importance of designing learning activities that foster reflective and meaningful human-AI interaction.

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