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Influence and Negotiation in Co-Designing an AI-Enhanced Multimodal Learning Analytics Platform for Secondary STEM Classrooms

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Abstract

This study examines how a transdisciplinary team experienced the co-design of an AI-enhanced Multimodal Learning Analytics platform for collaborative secondary Science, Technology, Engineering, and Mathematics classrooms. While artificial intelligence and learning analytics systems are often framed in terms of efficiency and personalization, far less is understood about how such systems are collaboratively designed across stakeholders. Drawing on sociocultural theory and participatory design, this study analyzes in-depth semi-structured interviews with four members of a co-design team engaged in a year-long, online collaboration. Using interpretative phenomenological analysis and theory-informed social network analysis, we examine both participants' lived experiences and patterns of influence shaping the co-design process. Findings show that co-design unfolded as a negotiated process across personal, interpersonal, and community planes. Educator expertise anchored problem definition and guided development, while roles and authority emerged through interaction. Care and trust sustained collaboration, and participation became a site of adult learning and identity work. Network analysis reveals a dense and reciprocal ecology of influence extending beyond the team. This study reframes co-design not as a procedural step for feedback incorporation, but as a relational process through which educational futures with AI are collectively imagined.

Keywords: Participatory Design, Artificial Intelligence, Learning Analytics, Collaborative STEM Learning, Sociocultural Theory.

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1. Introduction

Artificial intelligence (AI) and learning analytics (LA) are increasingly shaping educational innovation, yet limited research examines how transdisciplinary teams across educators, developers, researchers, and community partners co-design these systems in practice. Much AI in education research emphasizes personalization and efficiency, such as automated feedback and scalable decision-making (Penuel et al., 2026). However, responsible AI design raises broader questions about what counts as knowledge, whose judgments carry authority, and how communities participate in shaping AI in schools (Bang and Vossoughi, 2016; Penuel et al., 2026). Therefore, this study is situated within a participatory design initiative to develop an AI-enhanced Multimodal Learning Analytics (MMLA) platform for collaborative secondary Science, Technology, Engineering, and Mathematics (STEM)+AI classrooms. MMLA has emerged as a promising approach to analyzing learning through multimodal data streams, yet prior research remains largely confined to laboratory settings and resource-intensive infrastructures, with limited attention to authentic classroom contexts and community-engaged development (Cukurova et al., 2020). A recent review of 163 publications using multimodal sensing to capture collaborative processes showed that only 22% were conducted in naturalistic learning settings (Schneider et al., 2026).

Drawing on sociocultural theory and participatory design, this study examines how a transdisciplinary team experienced the co-design process. The analysis is based on four in-depth interviews with co-design team members, including an educator, developers, and a community partner within an ongoing international collaboration. Specifically, the study addresses two research questions (RQs): (RQ1) How do stakeholders in a co-design team describe the opportunities, tensions, and negotiation practices that emerge when co-designing an AI-enhanced MMLA system for collaborative STEM+AI learning? (RQ2) What patterns of influence relations are represented in the co-design network? The study contributes an empirically grounded account of co-design as a relational and human-centered form of educational innovation.

2. Conceptual Framework

This study conceptualizes co-design as a sociocultural and relational process shaped through participation, mediation, collaboration, and negotiated influence across personal, interpersonal, and community planes of activity (Bang and Vossoughi, 2016; Engle et al., 2014; Lave and Wenger, 1991; Rogoff, 1995; Wertsch, 1991). Building on participatory design and design-based implementation research, co-design is not treated as a feedback mechanism but as a process that engages with historicity, power, and relational dynamics across theory, method, and practice (Bang and Vossoughi, 2016; Penuel et al., 2011). Design decisions about data, collaboration, and authority are situated within broader histories of schooling and exclusion (Esmonde and Booker, 2017). Responsible innovation in education therefore requires attention to how, for what purposes, for whom, and with whom systems are designed (Penuel et al., 2026). Co-design is approached as a site of learning, negotiation, and collective imagining of educational futures and, in this context, learning and identity are understood as emerging through participation (Azevedo and Mann, 2022; Lave and Wenger, 1991). To examine how these processes unfold, we draw on Rogoff's three planes of activity: personal, interpersonal, and community (Rogoff, 1995). These planes serve as analytic lenses for understanding how participation is shaped across individual change, coordination with others, and broader institutional and historical contexts. We also draw on an influence framework (Engle et al., 2014), conceptualizing influence as interactionally negotiated shifts in participants' understanding or practice. Finally, AI is treated as a mediational means that both shapes and is shaped through participation, with its meaning emerging within ongoing social and educational activity (Wertsch, 1991).

3. Method

3.1. Study Context and Data Collection

This study builds on efforts to develop and deploy scalable, less intrusive MMLA approaches using AI-based methods for analyzing authentic STEM learning environments (e.g., Lee, 2025a,b; Lee et al., 2026a,b, under review). Prior work highlighted the importance of capturing diverse, especially nonverbal, forms of student participation and grounding analysis in classroom practice. To address this, the broader project is a participatory design initiative to co-develop an AI-enhanced MMLA platform for collaborative K–12 STEM classrooms across global contexts. The present study focuses on one site within this initiative: a research–practice partnership with a South Korean public school. It examines the first year of co-design, during which the team engaged in fully online collaboration, including regular meetings, messaging-based communication, iterative prototyping, and implementation in a high school physics classroom with 14 students. For 12 months, the team met (bi)weekly for 60–90 minutes with flexible agendas allowing any member to introduce topics. Activities included sharing experiences, discussing design directions, refining prototypes, and reflecting on how values such as equity and collaboration were translated into system features. The current version of the co-designed platform is available at `https://www.mltilab.com/projects/clear`. The team comprised seven members based in the U.S. and South Korea across roles, institutions, and time zones. Data consist of semi-structured one-on-one interviews with four participants (see Table 1), excluding the PI (the first author who conducted the interviews) and two researchers who joined the project at a later stage. Interviews focused on participants' experiences of collaboration, decision-making, and how pedagogical, ethical, and contextual considerations shaped the process. Conducted via Zoom in Spring 2026 (34–139 minutes; total 327 minutes), the dataset yielded 257 coded excerpts. This study was approved by the University of Virginia Institutional Review Board, and all research procedures strictly adhered to the approved protocol.

3.2. Research Design and Data Analysis

This study employed a novel mixed-methods design combining interpretative phenomenological analysis (IPA) and social network analysis (SNA) to examine complementary dimensions of the co-design process. First, IPA was used to analyze participants' lived experiences from interviews (Smith et al., 2021). The analysis followed an iterative process: Phase 1 developed descriptive accounts grounded in participants' perspectives; Phase 2 interpreted these accounts in relation to the conceptual framework, with attention to sociocultural planes (personal, interpersonal, community) (Rogoff, 1995); and Phase 3 refined and val-

Table 1: Participants overview

ID	Self-perceived role	Primary project contribution	Professional background
LE	Lead Educator	Design and classroom implementation	Secondary STEM teacher with 30+ years of experience; extensive experience designing collaborative and inquiry-oriented science/physics instruction
LD	Lead Developer	Technical coordination and development	Background in physics education and human resource development; 5+ years of web-service development, data analysis, and system design
JD	Junior Developer	UI/front-end development	Former science teacher; approximately 1.5 years of teaching experience, 1+ years of programming experience, and 2+ years of research experience
LM	Lab Manager / Community Partner	Facilitation and research–practice translation	Human resource development researcher and professional community organizer with 7+ years of research and professional experience

idated themes through iterative review. Second, to examine interactional dynamics, we conducted a theory-informed analysis of influence relationships using SNA. Influence was coded as shifts in understanding or practice associated with others' contributions (Engle et al., 2014). Directed ties (A→B) represent influence between participants. Coding included team members, external actors (e.g., students, other teachers and communities), and self-directed influence. Data were coded at the utterance level, with adjacency matrices constructed per participant and aggregated. Reliability was established through independent coding by three raters using multiple agreement metrics (percent agreement, Fleiss' κ, Krippendorff's α, Cohen's κ). All codes exceeded the acceptable threshold ($\geq .80$; mean $\kappa \approx 0.92$) across all metrics, following iterative refinement (McHugh, 2012). Networks were modeled as directed, weighted graphs, with node size reflecting total degree and edge width reflecting connection frequency. Multidimensional scaling (MDS) was also used to project relational structures into two-dimensional space (Borg et al., 2018).

4. Findings

Participants described co-design as an evolving, nonlinear process shaped by blurred structure, role construction, and negotiated authority. As LD noted, "people's intentions were clear, but their roles were not," reflecting fluid roles despite clear motivations. The process unfolded through ongoing alignment of classroom needs, technical constraints, and design expectations. LE emphasized that "almost every part of it was a compromise," highlighting the centrality of iterative revision in the co-design process. Unlike conventional research with predefined pathways, the absence of a fixed structure generated productive tension and supported adaptability. JD noted that shared decision-making limited individual control but strengthened collective ownership. Over time, roles emerged through interaction, with educators becoming more technically engaged, developers more attentive to pedagogy, and facilitation roles developing organically. Participants reported that early ambiguity functioned as a generative condition for collaboration.

Educator expertise and classroom need anchored problem definition and design direction. LE also described a pedagogical shift from an emphasis on individual performance toward collaborative learning. Observations of student behavior informed the design need for tools capturing authentic collaboration. Other participants treated educator expertise as central. JD shifted from interface-focused design to alignment with classroom practice, and LD emphasized grounding decisions in instructional realities.

Participants also described co-design as a site of collaborative learning and professional development. JD characterized the process as "one learning process," noting a shift toward user-centered thinking, while LD described how participation shaped his professional trajectory. LE described growth through engagement with new analytic and technical approaches. The analysis suggested that the co-design process supported both adult collaborative learning and identity work.

Care functioned as a central condition sustaining collaboration. Participants described both commitment to educational purpose and relational care. Trust, communication tone, and prior connections supported collaboration in a voluntary, distributed setting. LM highlighted maintaining a supportive atmosphere, while LD described the group as "loosely but agilely connected," operating without formal hierarchy yet maintaining shared direction. Moreover, despite differing perspectives on AI and LA, participants developed a shared understanding of how they intended to use AI in the co-design platform (i.e., not as a replacement for teacher authority but as a support for interpretation and collaboration).

Co-design also operated within a broader sociocultural ecology of influence extending beyond the immediate team. Participants described the co-design process as being shaped by students, AI systems, and communities. The combined directed, weighted network (Figure 1) across all four focal participants (LE, LD, JD, LM) includes 10 distinct actors and 46 directed edges. The network is relatively dense (density = 0.511) and highly reciprocal (weighted reciprocity = 0.81), suggesting a strongly interconnected collaboration ecology in which influence rarely flows in a single direction. This pattern aligns with participants' descriptions of blurred structure and negotiated authority, as the dense and reciprocal connections indicate frequent and bidirectional interaction.

Figure 2 presents individual influence networks for each participant (A: LE, B: LD, C: JD, D: LM). Figure 2(a) indicates that LE is closely connected with multiple participants across roles, with connections spanning students, developers, the lab manager, researchers, and AI, suggesting a bridging role across pedagogical and technical domains. Moreover, Figure 2(b–d) shows that other participants consistently reported strong connections to LE, indicating that the educator's expertise was frequently referenced and engaged throughout the co-design process. This pattern aligns with participants' accounts of the educator's role in shaping problem definition and design direction. Notably, LE was the only team member whose network included students as active relational nodes, suggesting that the student community entered the co-design ecology primarily through the educator's mediation. In contrast, other participants' networks (Figure 2(b–d)) show comparatively fewer

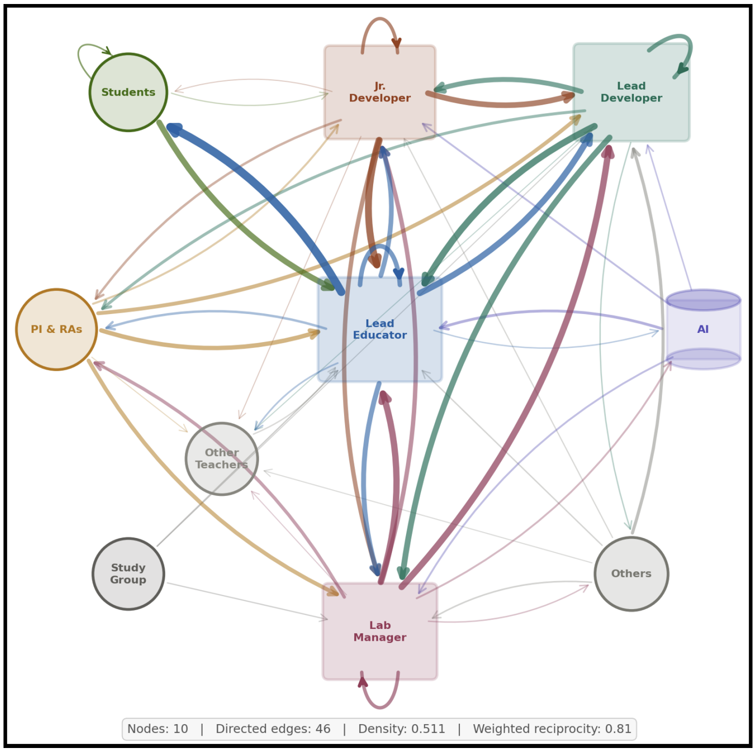

Figure 1: Combined directed weighted influence network

or weaker connections to classroom-related actors (e.g., students and other teachers), further highlighting differences in how classroom practice was represented across participants. In addition to interpersonal connections, the presence of self-loop patterns across participants' networks (Figure 2(a–d)) suggests that participants were not only interacting with others but also iteratively refining their own thinking over time. This pattern supports the interpretation of co-design as a space for collaborative learning and identity work.

The MDS layout (Figure 3) further shows the core team clustered closely, with external actors positioned more distantly but still connected. Influence was distributed across multiple actors, forming a complex, interrelated network. Overall, connections involving AI appeared comparatively sparse and less reciprocal, suggesting that AI functioned as a mediational resource, consistent with participants' descriptions of AI as a tool shaped by human judgment. This pattern varied across participants. LE and LM described weak bidirectional relationships with AI, whereas developers (LD and JD) more often described how AI shaped their work without similarly articulating how their own design decisions shaped AI in return. Given the multiple roles attributed to AI in the project, this relatively limited and asymmetric pattern of connection is notable.

5. Discussion and Conclusion

The study examined how a transdisciplinary team experienced the co-design of an AI-enhanced MMLA platform for collaborative STEM learning. First, co-design emerged as a

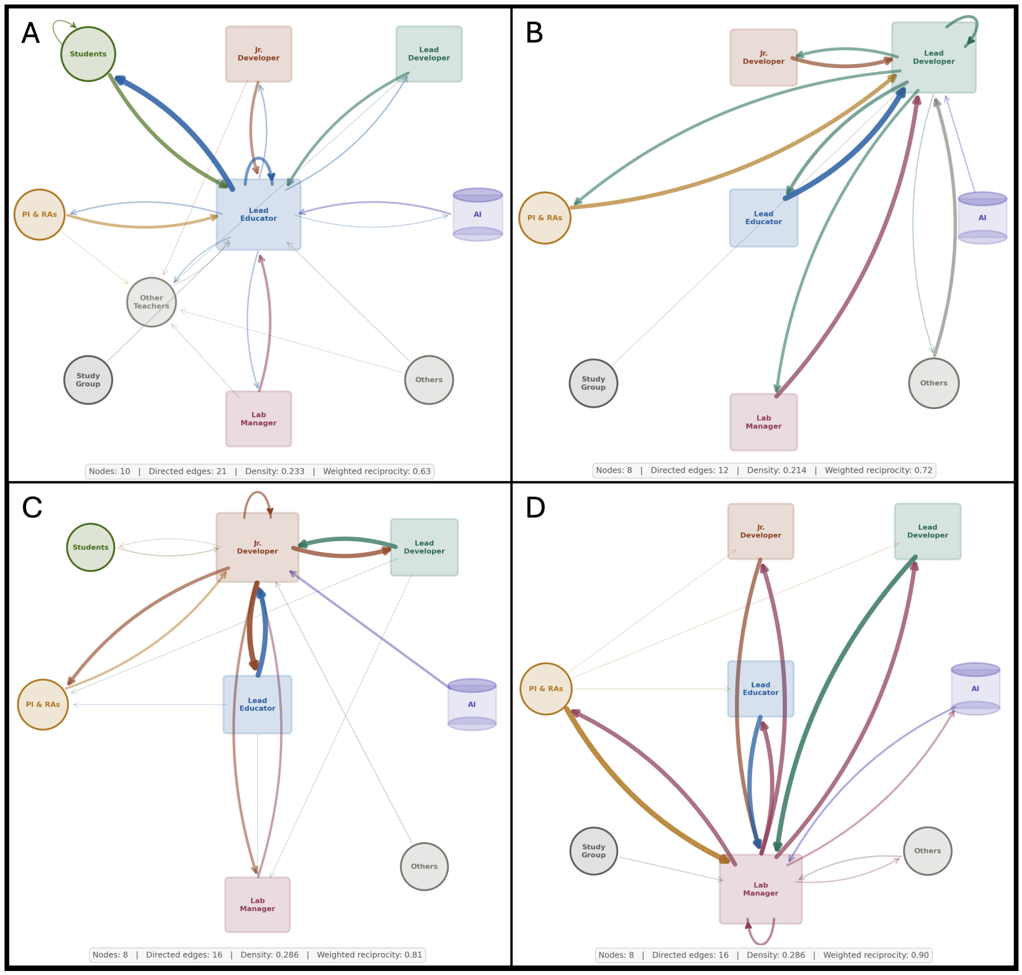

Figure 2: Individual directed, weighted influence networks (A: LE, B: LD, C: JD, D: LM)

complex relational process shaped across sociocultural planes, involving shared imagination and ongoing negotiation of purpose, authority, and participation (Engle et al., 2014; Rogoff, 1995). The process began with shared uncertainty and evolved through iterative interaction, where roles, goals, and directions were continuously reconstructed. Collaboration itself became a site of adult learning (Bang and Vossoughi, 2016). Second, the study highlights the importance of practice-centered responsible innovation. Educator expertise anchored problem definition and guided technical development, positioning classroom practice as the primary reference for design. This extends responsible AI scholarship by showing how innovation can take an educator-centered form (Penuel et al., 2026). Co-design redistributed authority across participants, challenging conventional researcher–educator hierarchies (Bang and Vossoughi, 2016; Penuel et al., 2011). Third, the findings show how care and trust are enacted through interaction. These dynamics were shaped through communication practices and facilitation and supported sustained participation, while flexible roles enabled contribution across boundaries. Co-design should be understood not merely as product

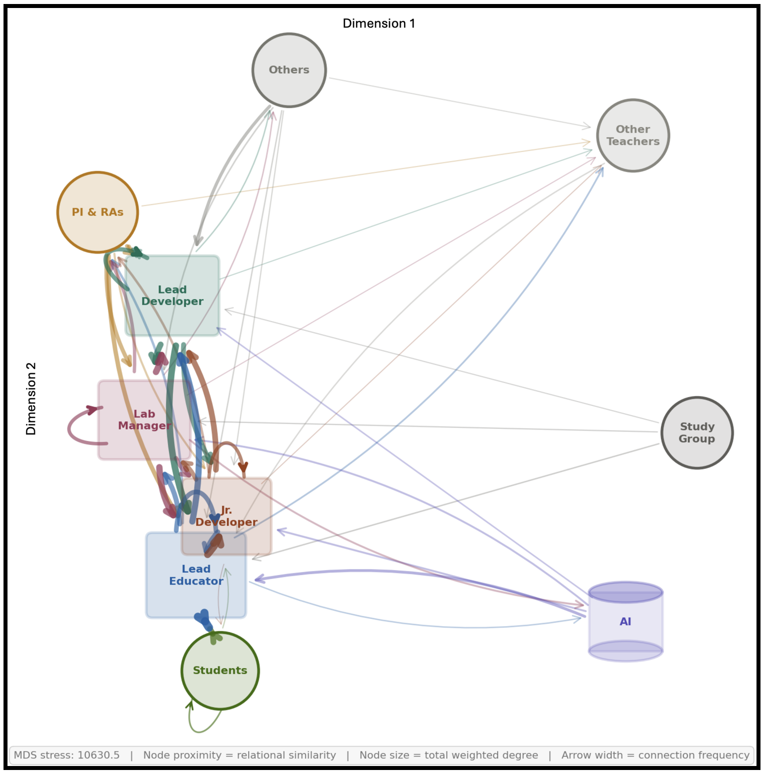

Figure 3: Two-dimensional MDS projection

improvement, but as relation-building and collective future-making (Bang and Vossoughi, 2016; Costanza-Chock, 2020). This study is limited by its reliance on retrospective interview data from a single co-design context. Future research can extend this work across multiple co-design initiatives and longitudinal data sources, including meeting records and design artifacts. Methodologically, this integrated phenomenological and network-analytic approach offers a transferable strategy for making the relational dynamics of co-design visible and inspectable across sites. Future applications across additional co-design contexts could compare variation in influence, reciprocity, educator mediation, classroom-community representation, and the position of non-human actors such as AI within broader design ecologies. This study calls for continued efforts to envision AI and LA systems that are accountable, interpretable, and designed with educational communities.

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