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From Provocations to Possibilities: Knowledge Building and the Future of CSCL with Generative AI

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Abstract

This paper examines Knowledge Building—past, present, and future—reflecting on its progress and situating its contributions within CSCL's visions and tensions to inform next-generation Knowledge Building and CSCL. Knowledge Building aligns with many CSCL approaches for collaborative knowledge construction while foregrounding collaboration as knowledge creation—an agenda much needed in the generative AI era for expanding CSCL's scope, identity, ecological and real-world impact. We first examine the foundations and goals of Knowledge Building, aligning theory, design, and technology for knowledge creation. We then review state-of-the-art Knowledge Building research and consider how it addresses CSCL visions and provocations, offering possibilities around scripting versus learner agency, collaborative groups versus communities, integrated design-based approaches, researcher-focused versus student-driven analytics, and bounded contexts versus open communities. Moving forward, we discuss how Knowledge Building can inform AI designs in CSCL and how generative AI can enrich Knowledge Building. Continuing with a knowledge-creation focus, we propose that AI designs should support transformation and idea improvement, advance community and public knowledge, balance guidance with epistemic agency, and develop technology as infrastructure for growing student epistemic capacity. We conclude by proposing future theoretical, methodological, and design directions, including broadening domains and contexts, engaging diverse learners and open communities, and studying collaboration at different scales for educational impact. Knowledge Building offers a future-oriented perspective that provokes new questions about collaboration, knowledge creation, and human–AI partnership in CSCL.

1. Introduction

CSCL, since its emergence in the 1990s, has developed from an emerging paradigm focused on how people learn with computers into a broad, multi-disciplinary field, spanning theories, designs, technologies, and methods, making major advances in analyzing collaboration processes and designing collaborative learning with technologies (Chan et al., 2025; Cress et al., 2021; Stahl et al., 2006). Despite this progress, CSCL is often viewed as a specialized field focused on group interactions; its designs and technologies remain confined to well-controlled settings, with limited impact on educational practice. Amid societal change and new educational demands, technological advances, generative AI (GenAI), and other communities studying collaboration, CSCL faces tensions and opportunities to broaden its identity, scope, and impact (Kaliisa et al., 2025). Various efforts have emerged to examine CSCL visions and provocations (Wise & Schwarz, 2017), CSCL identity and taxonomies (Simon et al., 2026), and calls to study collaboration at scale (Baker & Reinmann, 2024) and for impact (Stahl, 2015) in authentic, open ecological environments, particularly in a changing global environment transformed by GenAI.

This paper reviews Knowledge Building, a pioneering and enduring CSCL model that aligns theory, practice, and technology for knowledge creation, leveraging communities and systems design (Chan & van Aalst, 2018; Scardamalia & Bereiter, 2014, 2021). The focus on knowledge creation is much needed in the current global context and the GenAI era with new societal, educational, and technological

challenges. Knowledge Building development both reflects and addresses key progress and challenges in CSCL over recent decades, advancing theories, pedagogies, analytics, and technology design. Knowledge Building, provides conceptual grounding for rethinking current visions and provocations of CSCL around learning design, agency, community, analytics, infrastructuring, ecologies, and broader impact.

In this paper, we first outline the core ideas of Knowledge Building; then we discuss current state-of-the-art research in Knowledge Building as knowledge creation that addresses key CSCL visions and provocations. Next, we discuss theoretical and design directions for Knowledge Building-AI in CSCL, illustrated with research examples; finally, we discuss future development in Knowledge Building and its implications for CSCL.

2. Foundation of Knowledge Building: Theory, Design and Technology

Knowledge Building (KB), supported by Knowledge Forum (KF) (Scardamalia & Bereiter, 2014; 2021), aligns with CSCL goals of collaborative knowledge construction while foregrounding knowledge creation (Chan, 2013; Scardamalia & Bereiter, 2014). Knowledge Building focuses on knowledge construction as a social product that adds value to the community for the public good. In Knowledge-Building classrooms, students are positioned as members of a *knowledge-creating community* who treat their ideas as improvable conceptual artifacts to be built upon, tested, and refined through collective work to advance community knowledge and beyond (Scardamalia & Bereiter, 2014). In this sense, Knowledge Building involves sustained idea improvement through collective cognitive responsibility, with an educational agenda of helping students see their work as part of a civilization-wide effort to advance knowledge.

The origins and history of Knowledge Building trace back to research on writing, which characterizes productive writing as a knowledge-transforming process (Bereiter & Scardamalia, 1987), highlighting students' high-level agency. Bereiter and Scardamalia (1993) elaborate a surpassing-ourselves heuristics for continual idea improvement with strong parallels to modern accounts of knowledge creation (Gabora & Kauffman, 2016; Li & Kettinger, 2006). Gabora and Steel's Self-Other Reorganization (SOR) (2021) theory of knowledge creation views human culture and knowledge as evolving through self-organizing processes within minds and communal exchange between minds. This theoretical perspective aligns with the reciprocally linked individual and group processes in Knowledge Building, whereby individual contributions to community knowledge support both individual and collective knowledge advances (Bereiter, 2002).

Knowledge Building theory also draws on Popper's (1972) notion of three worlds: World 3, public knowledge, is distinct from physical objects (World 1) and mental representations (World 2) – the goal is to bring public, improvable World 3 knowledge into classrooms (Scardamalia et al., 1994). Among different CSCL theories (Stahl & Hakkarainen, 2021), Knowledge Building is identified as knowledge creation, alongside other CSCL trilogical theories (Paavola et al., 2004) that focus on shared knowledge objects, activity systems, or wiki-based knowledge creation.

Knowledge Building theory is instantiated in classroom pedagogy as an idea-focused, principle-based approach rather than one based on scripts and procedures (Zhang et al., 2011). Knowledge Building involves open classrooms where students pursue authentic problems, generate questions, propose theories and explanations, revise their understandings, and engage in progressive discourse. A set of Knowledge Building principles—including epistemic agency, improvable ideas, and community knowledge —informs Knowledge Building research, design, and technology (Scardamalia, 2002). Teachers often feel the pressure to implement assessment-bound routines that lack crucial attributes of knowledge creation. Knowledge Building principle-based approach encourages use of principles as design parameters for greater alignment with innovative practices for knowledge creation.

Knowledge Forum, formerly Computer-Supported Intentional Learning Environment (CSILE), (Scardamalia & Bereiter, 1991) provides a collaborative space where students contribute questions, theories, explanations, evidence, and synthesis using discourse and multimedia as public objects for inquiry. Features include Views, build-ons, scaffolds, references, and rise-above notes that help students organize inquiry, connect ideas, synthesize advances, and develop higher-level conceptual perspectives. KF includes assessment and analytics tools that make students' activities, interactions, scaffold use, and conceptual progress visible, as well as objects for reflection.

Related technology development, including Idea Thread Mapper (Zhang et al., 2018), Promising Ideas (Chen et al., 2015), and Knowledge Building Discourse Explorer (KBDex, Oshima et al., 2012), supports students' ongoing reflection on idea development and enhances shared agency. Knowledge Building theory, pedagogy, and technology are tightly coupled -- researchers, teachers, and engineers work in multidisciplinary teams, and technologies are tested and designed in classrooms for iterative improvement.

Over the past four decades, Knowledge Building research has developed along several key lines of inquiry. First, design-based research has advanced pedagogy and theory while restructuring classroom practice across subject areas, from STEM to literacies and art design (Chen & Hong, 2016; Davies et al., 2024; Tan et al., 2014; Teo, 2024; Tong & Chan, 2023; Vokatis et al., 2026; Zhang et al., 2011). Second, Knowledge-Building analytics and tools such as Knowledge-Building Discourse Explorer (KBDeX) have been developed to visualize idea connection and collective advance (Oshima et al., 2012) enriched with reflective assessment (Yang et al., 2000; Yang et al., 2024). Third, research is expanding CSCL small-group interaction toward cross-community Knowledge Building, enabling boundary-crossing and collective advancement across contexts (Cao et al., 2025; Yuan et al., 2022; Zhang et al., 2020). Fourth, research on infra-structuring, school-university partnership, and teacher communities extends Knowledge Building from classrooms to networked and system-level transformation (Chan, 2011; Lafferriere et al., 2010; Tan et al., 2021). Taken together, these advances position Knowledge Building for theoretical, pedagogical, technological, and infrastructural innovation with continuing development.

3. CSCL Provocations and State of the Art Knowledge Building Research and Innovation

This section discusses current research advances in Knowledge Building aligned with CSCL questions, specifically addressing CSCL visions, provocations and possibilities (Wise & Schwarz, 2017).

3.1 Epistemic agency for dynamic Knowledge Building: From scripting to co-structuring

A central challenge in CSCL is to guide collaborative interaction effectively while enhancing students' agency for creative knowledge work (Wise & Schwarz, 2017). A common approach uses collaboration scripts to guide learners by specifying and sequencing task operations for group work (Kirschner & Erkens, 2013). Yet such pre-scripted guidance constrains epistemic agency: students' individual and collective control over key components of Knowledge Building such as goals, idea-advancing moves, inquiry tools, and collaborative roles (Damşa et al., 2010; Scardamalia & Bereiter, 2006). Knowledge Building research offers an alternative. Zhang et al. (2018, 2022) examined agency-enhancing guidance structures that are not preset by teachers or researchers but co-constructed by students bottom-up as their knowledge work evolves. Through this process, which Zhang et al. (2018) term reflective structuration, the community collectively reflects on its work to create and revise shared structures that frame its inquiry goals, processes, groupings, and criteria (expectations).

In a Grade 5 science classroom, for example, students formulated "juicy" inquiry areas from emerging questions and interests. They mapped these areas visually to guide participation and reorganized them as new directions and connections emerged. Small groups formed and re-formed to advance knowledge in the evolving areas. Such student-generated structures enhance student agency for shaping and reshaping their knowledge-building process while also providing guidance for collaborative interaction for building deep understanding (Tao & Zhang, 2018, 2021; Zhang et al., 2018). Teachers sustain this student-driven process through reflective noticing and responsive scaffolding. They attend to ideas and interests emerging in student discourse, interpret inquiry directions, progress, and needs in light of the curriculum, and build on students' ideas and questions to catalyze deeper thinking and expand inquiry (Ko & Krist, 2019; Park & Zhang, 2025).

3.2 Sustaining Knowledge Building beyond small groups: Across classrooms and into society

To transform education, CSCL research needs to examine how collaborative learning can be sustained at higher social levels and at larger scales (Baker & Reinmann, 2024; Chen et al., 2021; Law et al., 2021; Stahl, 2013; Wise & Schwarz, 2017). In response, a growing line of Knowledge Building research has tested designs for cross-community collaboration, ranging from links between classrooms to partnerships with real-world organizations. An early design opened each classroom's discussion space to partner classrooms, so students at different schools could read and build on one another's work (Laferrière et al., 2012; Lai & Law, 2006).

More recent research has tested a multilayer approach. As students in each classroom build knowledge in their home discourse space, they also share progress and challenges in a *meta-space* shared across classrooms. There, they post "super notes" to synthesize and exchange their inquiry progress. Interaction in the meta-space enables knowledge to flow across classrooms, forming an expanded ecology for knowledge building (Sun & Zhang, 2025; Yuan & Zhang, 2019; Yuan et al., 2022; Zhang et al., 2020). Another model engaged students across grades 2 and 9 in Canada and Spain to address sustainable development (Cao et al., 2025). To extend Knowledge Building into real-world settings, a design experiment tested school–community partnerships that support students in conducting authentic research with professional organizations focused on pressing local and global issues (Underwood et al., 2025). The findings point to new possibilities for embedding student Knowledge Building in the broader knowledge-creating culture (Bereiter, 2002), as students join the ranks of real-world knowledge builders who advance knowledge for the social good.

3.3 Design-based approach: Integrating analytics-computational and interpretive analyses

CSCL methods are diverse, reflecting varied goals, theories, designs, and tools (Hmelo-Silver & Jeong, 2021). While quantitative-analytic and qualitative-interpretive approaches have been viewed as incommensurable (Wise & Schwarz, 2017), Knowledge Building has developed a design-based methodological orientation that integrates multiple analyses and multimodal data to advance analysis, design and theory.

CSCL analytic approaches typically code collaborative discourse moves, trace interactive contributions, and link these patterns to learning outcomes. Knowledge Building has developed analytic approaches that align theory with analysis. For example, inquiry threads and community views (Zhang et al., 2007) are used as units of analysis to examine collective idea advances rather than individual contributions. Analyses have distinguished knowledge sharing, knowledge construction, and knowledge creation, linking analytic categories to theory (van Aalst, 2009). With CSCL's emphasis on temporality (Hmelo-Silver & Jeong, 2021), research has used epistemic network analysis, lag-sequential analysis, and automated analyses to trace temporal dimensions and trajectories (Yang et al., 2024). As well, qualitative-interpretive lenses are also used, including thematic analysis, case studies, and activity-system perspectives, to explain how students pursue idea development and grow identities as knowledge builders (Rahmian et al., 2024), how inquiry groups and epistemic norms emerge (Siqin et al., 2015; Zhang et al., 2009, 2022), and how classroom culture, tool use, and teacher scaffolding support Knowledge Building (Park & Zhang, 2025; Teo, 2024).

Knowledge Building uses a design-based approach that integrates analytic and interpretive methods focusing on designs, effects, and dynamics. Quantitative analyses show broad patterns and effects, while interpretive analyses illuminate meanings and mechanisms, explaining why certain patterns matter across designs identifying enabling conditions. Zhang et al. (2018) used quantitative analysis to compare the scientific sophistication of explanations across Idea Thread Mapper designs, while

qualitative and video analyses traced the temporal unfolding of collaborative inquiry. Soliman et al. (2026) identified design conjectures supporting modelling, coded KB discourse for systems thinking over time, and used student artifacts, including Idea-Friend maps (Feng et al., 2021), to show how modelling supported deeper discourse. Design-based methods could coordinate multiple methods and multi-modal data sources advancing design and theory for impact.

3.4 Collaborative learning analytics and embedded, concurrent and transformative assessment

Knowledge Building has pioneered analytics (Chen & Zhang, 2016; Hong et al., 2015), beyond researcher analysis to learner-driven analytics, addressing provocations (Wise & Schwarz, 2017) and challenges including representing analytics at appropriate level, moving from visualization to action, and shifting from research tools to classroom impact (Wise et al., 2021).

Knowledge Building analytics, guided by the principle of embedded, concurrent, and transformative assessment, integrates theory, designs and tools supporting student agency (Ng et al., 2024) Knowledge Forum includes embedded assessment-analytics tools accessible to students to reflect on and monitor their discourse, enriched with classroom meta-talk. Resendes et al. (2016) show that Grade 2 children use visualization (word clouds) and meta-talk to examine what a community understands for making further progress. Analytics-supported reflective assessment shows how analytics provide visualization of discourse, enriched by discussion prompts, as students engage in metacognitive and collective reflection. Multiple studies show how students used visualizations of Knowledge Forum discourse from Knowledge Connection Analyzer, KBDeX, ENA, and AI tools to examine the current state of community knowledge, identify connections, emerging questions, and regulate next-step inquiry (Yang et al., 2020; Yi et al., 2025; Zhang et al.,2018). KBDex, commonly used for research analysis, is adapted as Idea-Friend maps (Feng et al., 2021) for young learners to support discourse, reflection, nd systems thinking (Soliman et al., 2026).

Knowledge-Building analytics have also been adopted with diverse learners (Yang et al., 2020), and supporting emotions (Yang et al., 2022; Zhu et al., 2022). Analytics visualization has also moved beyond Knowledge Forum discourse to include multimodal data, such as video-based and neuroscience data, informing teacher actions in professional networks (Teo et al., 2022; Yuan et al., 2026). Knowledge Building has demonstrated how analytics can be designed to support agency, reflection, and discourse in open environments for broader real-world impact.

3.5 Infra-structuring, partnership, and teacher communities for systemic change

A major vision and provocation for CSCL concerns impacting educational practice (Wise & Schwarz, 2017), tackling researcher–practitioner relationships (Simon et al., 2026), and supporting scaling and sustainability (Law et al., 2021). Knowledge Building research moves beyond classroom designs to infra-

structuring, partnerships, teacher communities, and Knowledge Building networks-collaboratories for systemic change.

Knowledge Building highlights social practice in classroom (Bielaczyc, 2006), aligning with current shifts from technology to infra-structuring (Baker & Reimann, 2024). Innovations often fail when technology is treated as stand-alone tools. Chen (2024) discussed *infra-structuring* as parts of wider social, technological, organizational, and material arrangements - creating social practice connecting curriculum standards, assessment routines, technologies, teacher roles, and local constraints. Thus, beyond introducing new tools-platforms, researchers and practitioners redesign how innovations connect with local routines and possibilities. For example, in the IdeaMagnets study (Chen et al., 2020), science teachers acted as co-designers who identified constraints such as limited devices while adapting the design to students' concerns and locally workable technological arrangements.

Knowledge Building research has also examined collaboration at scale through multi-level, multi-stakeholder partnerships for systemic change (Chan, 2011). Studies have also shown how school–university–government partnerships and multi-level networks support innovation by aligning classroom inquiry, researcher expertise, policy resources, and technological infrastructure (Laferrière et al., 2012; Tan et al., 2021). Technology development is also tightly coupled with pedagogy through multidisciplinary teams and classroom iterative testing.

Knowledge Building research has examined how teacher communities and networks support sustained innovation and practice. Teachers are designers who use Knowledge Building principles, not scripted designs, making it more possible for them to engage in knowledge-creation (Chan, 2011; Teo, 2014, 2019, 2024; Zhang et al., 2011). Teacher communities are also Knowledge-Building communities where they design and test and innovate; these teacher communities across countries are connected through Knowledge Building International (KBI, https://ikit.org/kbi/), formerly Knowledge Society Network (KBS). KBI and Knowledge-Building Collaboratory create spaces for principle-based innovation, enabling practitioners, researchers, engineers, students, theorists, and policymakers to identify interdisciplinary connections, problems, assessments, and designs across communities. A design experiment analysing Knowledge Forum community data demonstrated network dynamics and growth, identifying design improvements for the KBS (Hong et al., 2010). These developments suggest possibilities for CSCL to move beyond localized, bounded contexts toward open ecologies of collaboration for wider theory–practice synergy and impact

4. Knowledge Building and Generative AI

Moving forward, a major direction is conceptualizing and integrating GenAI for Knowledge Building and CSCL. Knowledge Building has a certain affinity with GenAI, with shared concerns about how people work with knowledge (Bereiter & Scardamalia, 2025). We discuss how Knowledge Building can inform CSCL-AI designs and how AI can contribute to Knowledge Building, and we include research examples that illustrate these possibilities.

4.1 Knowledge Building informing and reciprocally enriched by AI designs

4.1.1 Sustained Idea Development

While GenAI research has provided positive results, an intriguing finding is that it has also led to decreased cognitive capacity and metacognitive laziness (Fan et al., 2024; Wegerif & Casebourne, 2025). Cress and Kimmerle (2023) discussed designing GenAI for CSCL dialogic interaction grounded in knowledge transformation, contrasting it with knowledge telling (Bereiter & Scardamalia, 1987). While novices retell what they know, expert writers iteratively restructure ideas to transform their understanding. Knowledge transformation continues to develop to *sustained idea improvement (See* Section 2*)*, relevant for characterizing how students work with GenAI today – passive retelling of AI input versus sustained work with AI for knowledge transformation. The distinction between *belief mode* and *design mode* in Knowledge Building further clarifies the dynamics: beyond verifying and evaluating AI outputs, students need to work in design mode, treating information and ideas—from peers and AI—as improvable objects to elaborate, test, transform, and integrate into new coherent explanations with continued pursuit and improvement.

These conceptual distinctions in Knowledge Building could possibly explain contradictory AI research findings; at the same time, AI could deepen discourse when designed around core ideas of transformation, with student-AI working as epistemic partners (Yi et al., 2025). Knowledge Building theory suggests developing students' design-mode thinking and sustained pursuit of inquiry. Designing CSCL-AI environments should support progressive discourse, so that AI extends, deepens, and transforms inquiry rather than short-circuiting students' thinking or replacing collaborative knowledge work.

4.1.2 Community and Public Knowledge

From a Knowledge Building perspective, GenAI systems are reshaping the ecology of collective knowledge itself, changing how people encounter, generate, synthesize, and circulate knowledge. When GenAI responses enter a shared Knowledge Building collaboration space, they need to become objects of shared cognition and community advances, not just individual understanding. Meta-discourse in Knowledge Building – discourse about discourse – involves learners stepping back to see what has been accomplished by the community for deepening inquiry and new questions, enabling advances in community knowledge at progressively higher levels. AI is adept at producing summaries but lacks *explanatory coherence* (Bereiter & Scardamalia, 2025). Knowledge Building work with AI in early years showed how upper elementary school students worked with Thagard's computational model of explanatory coherence called ECHO (1989, 2007), using AI to improve their understanding of AI and restructuring ideas. Further work on explanatory coherence is needed beyond summary to trace idea trajectories, surface unresolved tensions, identify gaps between evidence, explanations, and community

goals for generating theories and creative work at higher planes. What is central is supporting students taking executive action in AI-human collaboration in advancing community knowledge.

The focus of Knowledge Building on community and public knowledge also seeks to expand World 3 knowledge aligned with cultivating collective intelligence and inducting learners into a broader culture of thinking (Wegerif & Casebourne, 2025). Just as scientists increasingly work with AI to do science (Erduran, 2023), students need to be educated to use AI to develop epistemic practice of creating community and public knowledge. Knowledge Building is a social system that aims to democratize and create public knowledge, and GenAI offers potential for knowledge creation and deeper educational goals. Designing KB-AI environments that emphasize community knowledge would help students see their work extend beyond local groups or classroom contexts, participating in long-term cultural and scientific dialogues.

4.1.3 Epistemic Agency

GenAI in CSCL has many benefits, but it has also brought about widespread concerns about students' over-reliance and cognitive offloading (Fan et al., 2024). The Knowledge Building principles, especially epistemic agency, provide guidance for examining and designing AI-human collaboration (Woodruff & Hewitt, 2026; Wu et al., 2025). Epistemic agency involves students actively engaging in knowledge formation, pursuing epistemic goals, grappling with their own and peers' ideas and scientific models, and steering their intellectual progress. Epistemic agency is a central function of human minds in the age of AI, shifting from intellectual operators who perform cognitive work to "intellectual stewards" who govern cognitive work distributed across human and AI systems (Zhang, 2026).

As intellectual stewards, students make reflective judgments about what knowledge is worth advancing, how knowledge work should be organized across human and artificial agents, what actions are right and ethical to take in a specific context, and what risks they entail. They treat AI outputs as objects for examination, revision, and further inquiry, take thought-demanding paths over cognitive shortcuts, and deliberately regulate AI use for advancing personal growth and collective good. GenAI designs may restrict epistemic agency, but they may also create new affordances for distributing and supporting it as students work with constraints and affordances. Chen (2026) argued that GenAI should not be treated as mere tools, but as "epistemic infrastructure" that provides affordances for skilled epistemic action, supports epistemic sensitivity, and creates conditions for habit formation. A major design focus is balancing AI guidance support and epistemic agency (see Sections 3.1 and 4.2).

KB principle-based designs could support epistemic agency in KB-AI environments. A principle-based approach asks how AI can enrich the conditions for realizing core Knowledge Building principles, such as improvable ideas and rise-above, by developing enriched environments that students and teachers can adapt. Cacciamani & Khanlari (2025) discuss a principle-based approach that identifies Knowledge Building actions and competencies AI might support, examines how these actions connect to valued Knowledge Building principles, and designs chatbot functions aligned with them. Key CSCL implications include designing GenAI tools that not only scaffold activities and outcomes but also leverage principles,

building epistemic infrastructure, foregrounding student ownership, responsibility, and shared agency to advance knowledge.

4.1.4 Next-Generation Knowledge Forum and Analytics

CSCL research has shown major progress in AI-learning analytics, yet fewer studies have incorporated them into classroom situations (Ouyang & Zhang, 2025). Since the creation of CSILE/Knowledge Forum, KB technology has focused on enabling and building student agency and capacity (Scardamalia et al., 1992), now even more relevant with GenAI. The central question for design: Is the epistemic agency with AI or with the students? Pilot studies are showing the power of epistemic markers for overcoming metacognitive laziness and overreliance on AI ("What AI missed…" "What is likely wrong in this AI analysis…") and idea improvement as students cite AI and improve on its input.

An MCP server is now incorporated into Knowledge Forum, and knowledge-building analytics are making processes by which knowledge created is transparent and actionable. For example, visualizations are used to show concepts in the community discourse in relation to relevant benchmarks (e.g., curriculum documents, lectures,) ordered by increasing complexity to show idea trajectories (Teo & Ong, 2026). Students can find redundant information, connect with near- and far-neighbor ideas, support deepening discourse moves, and taking responsibility for knowledge advances. Importantly, AI-powered analytics need to be embedded, concurrent, and transformative, available in real time for self-improvement as it proceeds - expanding to learner focus, turning analysis into action for goal setting, regulation, identifying progress and gaps, and steering human–AI collaboration toward knowledge advancement

4.2 Knowledge Building-AI research examples

4.2.1 Knowledge Building-AI Designs

Knowledge Building-GenAI research is just emerging, and we include examples to illustrate some possibilities. Lee et al. (2025) used a Knowledge Building database to simulate how GenAI could be designed, focusing on enriching Knowledge Building principles for advancing deepening discourse. GenAI could support idea generation, idea improvement and rise-above synthesis for emerging questions. Particularly, GenAI goes beyond summary by comparing online discussion themes with authoritative sources and identifying what themes show gaps in need of attention. Examining Knowledge Forum discussion for meta-discourse supported by GAI could support idea improvement and rise-above for creative knowledge work.

Yang et al. (2026) examined the role of AI and analytics enriched by reflective assessment for Knowledge Building. Preservice teachers first discussed initial design plans on Knowledge Forum pursuing collective inquiry, followed with human-AI collaboration for refining designs and discourse; this iterative sequence encourages sustained idea improvement while increasing epistemic agency. This process further enriched with analytics-supported reflective assessment- students reflected on community progress in KF discourse using KBDeX visualization, enriched with reflection prompts inquiring into idea connections, current gaps, and emerging questions. Through this iterative cycle—

human-driven discourse, AI-iterated refinement, and analytics-informed reflection- student advanced in deepening their community discourse while improving on design and research inquiry. Knowledge-Building AI designs primarily centre on idea improvement and epistemic agency, enriched by reflective assessment and analytics for deepening knowledge advances

4.2.2 Expanding from Classrooms to Teacher Communities and Networks

In Knowledge Building, teachers are not consumers of GenAI but designers taking up agency improving practices in communities, networks and collaboratories. Hong et al. (2025) showed that embedding ChatGPT within a "sustained idea-developing discourse" (SIDD) framework in Knowledge Forum for pre-service teachers increased idea synthesis, as teachers interrogated GenAI content, increasing agency, not displacing it. Tan et al. (2026) developed a learning companion chatbot for teachers to understand and implement the principles-based approach to Knowledge Building. The design positioned teachers as active sense-makers and knowledge builders taking up agency as they reconciled the theoretical complexity of Knowledge Building with the practical demands of classroom implementation. Cheng et al. (2026) investigated teachers using AI-supported "craftpads" to design Knowledge Building lessons, positioning teachers as designers rather than end-users of AI, emphasizing "meta-design," which empowers educators to configure and adapt tools for their aspirations and needs. The environment combined an infinite canvas for flexible ideation, an embedded prompt library grounded in knowledge-building principles to guide AI-generation tasks, and a flexible workflow to help teachers iteratively refine AI-design artifacts. Throughout, teacher agency and judgment remained primary with AI serving as a resource subordinate to teachers' expertise and creative agency.

Across these studies, the focus is on sustaining and deepening teacher agency with community ethos and infra-structuring, rather than adopting AI as an autonomous instructional solution. Whether through critically verifying AI output within collaborative discourse (Hong et al., 2025), negotiating theory-practice tensions (Tan et al., 2026) or reconfiguring tools through meta-design (Cheng et al., 2026), teachers act as epistemic agents working in design communities connected with others in networks. AI expands their elaborative and generative capacity, but they make judgment valuing agency. Integrating GenAI for teachers' knowledge creation positions them as inventors and knowledge builders, also developing capacity to work within a global network of Knowledge Building Collaboratories.

5. Summary and Future Directions

This paper has reviewed Knowledge Building, past, present and future, highlighting its development and contributions to CSCL. Knowledge Building offers a knowledge-creation lens for addressing CSCL visions and tensions also conceptualizing human–AI collaboration, and for broadening CSCL's real-world impact.

Following introduction to Knowledge Building foundation, we discuss state-of-art research aligned with CSCL visions and provocations (Wise & Schwartz, 2017). Using a knowledge-creating lens, the research

findings reveal new possibilities around scripting vs. learner agency, collaborative groups vs. communities, incommensurable methods vs integrative design-based approach, technology-focused vs. learner-driven analytics, bounded context vs. infrastructuring and open communities. We also discuss how Knowledge Building could inform AI-CSCL designs and emerging KB-AI development that foregrounds sustained idea improvement, community knowledge, epistemic agency, and agency-focused technology for co-creation in classrooms and teacher communities.

Looking forward, Knowledge Building research will draw from the richness of CSCL for future development. Theoretically, Knowledge Building can further develop and expand knowledge-creation in CSCL by enriching conceptual and analytic frameworks, particularly theorizing and examining co-creation in human-AI collaboration. AI-enriched KB-CSCL environments could consider explanatory coherence for theory building and community knowledge advancement, and examine how students engage in knowledge transformation and creative knowledge work in AI-enriched CSCL environments.

Designing for epistemic agency in KB-CSCL environments is central to addressing concerns about dependence on AI and cognitive offloading. AI should not be considered only a tool but an epistemic infrastructure that enables conditions for developing epistemic agency, and principle-based designs could open up possibilities. Further research and design must balance guidance and student agency in CSCL. Key questions include: How can AI scaffold student collaborative discourse while enhancing agency for directing inquiry? What design principles help learners sustain, adapt and improve AI contributions? How do the different choices students make in AI-supported work shape/reshape their knowledge building process and long-term developmental trajectories?

Methodologically, Knowledge Building could continue to expand AI technology-analytic approaches toward human-centered analytics focusing on epistemic agency and reflective assessment for knowledge creation. CSCL research is fast progressing in AI-enriched automatic and multi-modal analyses. Implications include enriching them with theoretical basis and designing learner–driven AI-multimodal analytics interventions in classrooms and different collaboration contexts for increased validity and impact.

Knowledge Building’s emphasis on democratizing knowledge also points to the need to design for diverse learners and to broaden attention beyond cognition to include emotion and culture. Future CSCL research should examine how AI environments can support equity, identity, affect, and multiple forms of contribution. Research on teacher communities further shows that sustainable innovation depends on infra-structuring that connects networks of teachers, researchers, and communities. Further CSCL studies could investigate collaboration at scale and examine how AI-enriched designs and analytics can support new forms of collaboration. Knowledge Building provides CSCL with a future-oriented framework for theorizing and designing human–AI ecologies in which AI, learners, and teachers work together to advance collective knowledge.

Declarations

Author Contribution

CKK: Conceived and coordinated writing project: conceptualized structure /theoretical arguments; wrote most sections and revised paper JW: Conceptualized and developed structure and arguments; wrote some key sections and critically refined paperMS: Refined key arguments to strengthen paper; added writing and edited throughout CB: Contributed to key conceptual ideas and direction of paper

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