

Stackable Skills for Knowledge Building Teachers: Infrastructure for Practice and AI Augmentation

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Working Paper 02/2026

Abstract

Knowledge Building (KB) pedagogy demands sophisticated teaching practices that many educators find challenging to develop and sustain. This paper presents a framework of decomposed, stackable teaching skills grounded in KB principles as an evolving infrastructure for KB teaching and technology development. I begin by examining what teaching involves as complex professional work, then articulate what KB teaching specifically requires, including explicit engagement with the twelve KB principles. From this foundation, I introduce a preliminary set of interconnected skills of KB teaching organized into four domains. I illustrate the framework with a concrete example and argue that this skills framework provides workable infrastructure (Chen, 2024) for advancing the KB community, supporting human teachers through explicit skill decomposition while creating foundations for future AI augmentation that preserves teacher agency in KB classrooms.

Keywords: Knowledge Building, teaching practice, professional infrastructure, epistemic agency, teacher augmentation

Teaching as Professional Practice

Understanding how to support KB teachers requires first understanding what teaching involves as complex professional work. The foundational work by Shulman (1987) is represented by the conception of pedagogical content knowledge (PCK), the distinctive amalgam of content and pedagogy that constitutes teachers' professional knowledge. Shulman argued that effective teaching requires more than subject matter expertise or generic instructional techniques; it demands understanding how to represent ideas for particular learners, anticipate misconceptions, and transform content into teachable form.

Grossman and colleagues extended this work by articulating teaching as a profession with identifiable practices that can be decomposed, learned, and refined. In their framework for teaching practice, Grossman, Compton, et al. (2009) identified core practices, high-leverage activities central to professional work, that cut across professional domains. For teaching, these include eliciting and responding to student thinking, leading discussions, and explaining concepts in accessible ways. Crucially, this work established that complex professional practice can be decomposed into learnable components without losing sight of how components integrate in authentic performance (Grossman, 2011).

This decomposition approach has proven generative for teacher education. Grossman, Hammerness, et al. (2009) demonstrated how novice teachers can develop expertise through rehearsal of discrete practices before facing the full complexity of classroom performance. More recently, Kavanagh et al. (2020) showed how approximations of practice enable teachers to develop responsiveness to

student thinking through structured preparation. Teaching expertise develops through progressive integration of component skills, not through exposure to holistic complexity in a condensed timeframe.

To support teachers, whether through professional development, curriculum materials, or technology, it is sensible to identify the component practices of effective teaching, create infrastructure that supports their development, and design for progressive integration toward expert performance. If teaching can be understood as complex work composed of identifiable, learnable practices, then KB teaching, as a specific form of teaching, should be similarly analyzable and supportable. The key question becomes: *What are the distinctive practices that constitute KB teaching, and how might infrastructure support teachers in developing them?*

What Knowledge Building Teaching Requires

KB pedagogy places distinctive demands on teachers that build upon but extend beyond general teaching competencies. Where traditional instruction positions teachers as knowledge deliverers and students as knowledge receivers, KB reconceptualizes the classroom as a community engaged in collective knowledge advancement (Scardamalia & Bereiter, 2006). Students take epistemic agency, being genuinely responsible for identifying problems, developing theories, and improving ideas through communal discourse.

The KB Principles

KB pedagogy is organized around twelve principles that articulate what knowledge-building communities should accomplish (Scardamalia, 2002). These include commitments to real ideas and authentic problems (students work on genuine issues and ideas), improvable ideas (ideas are objects to be refined), idea diversity (multiple perspectives advance understanding), rise-above (synthesis creates higher-level concepts), epistemic agency (students direct their own inquiry), community knowledge and collective responsibility (the group owns knowledge advancement), democratized knowledge (all members contribute), symmetric knowledge advancement (participants support each other's growth), pervasive knowledge building (KB extends beyond designated times), constructive use of authoritative sources (sources inform rather than replace student thinking), knowledge-building discourse (conversation develops ideas), and embedded, transformative assessment (assessment serves learning).

Collectively, these principles describe a classroom culture markedly different from traditional instruction. For teachers, enacting them requires specific competencies that go well beyond understanding the principles conceptually. Not relying on prescribed scripts offers valuable flexibility for experienced practitioners, but this same openness can leave novice teachers puzzled about where to begin (Chen & Hong, 2016; Chuy et al., 2011).

Teacher Competencies for KB

Scardamalia (2002) distinguished three teacher orientations: Teacher A focuses on transmitting established knowledge; Teacher B manages engaging activities; Teacher C cultivates students as knowledge creators who take collective cognitive responsibility for advancing community understanding. KB requires Teacher C, a stance that transforms traditional conceptions of what teachers need to know and be able to do. KB teachers must:

Identify authentic problems. Rather than presenting predetermined questions with known answers, KB teachers work with students to identify problems they genuinely care about, problems that connect to their worlds and admit real uncertainty. The principles of real ideas, improvable ideas, and pervasive knowledge building cannot be enacted without this competency.

Facilitate productive discourse. KB depends on talk that builds ideas rather than merely shares them. Teachers must orchestrate discussions where students respond to each other rather than through the teacher, where disagreement leads to evidence-based resolution, and where periodic rise-above synthesis advances community understanding. This facilitation is improvisational; teachers must make real-time decisions about when to probe, when to step back, and when to redirect (van Es & Sherin, 2002). The knowledge-building discourse principle requires this competency.

Assess epistemic progress. Traditional assessment asks what individual students know. KB assessment asks whether the community is advancing understanding, whether ideas are improving, and whether individual contributions serve collective progress. Assessment is not the teacher's job alone; teachers involve students in assessing their own learning to transform what they do and build. The embedded, transformative assessment principle requires approaches that many teachers find unfamiliar.

Preserve student agency. The most difficult aspect of KB teaching may be knowing when not to intervene. Teachers habituated to providing answers must instead create conditions for students to develop answers. Support that over-scaffolds can undermine the epistemic agency at KB's core (Bielaczyc & Ow, 2014).

These demands explain why KB, despite decades of research demonstrating its potential, remains challenging to implement at scale. Conceptual understanding of KB principles is difficult given their complexity; translation to practice is harder still given the openness of principle interpretation and their distance from common practice; and all of this unfolds within the varied complexity of classroom realities across different educational systems.

A System of Stackable KB Teaching Skills

To support KB teachers, I have developed a repository of teaching skills organized into four domains.¹

This work draws on my argument that sustainable educational innovation requires workable infrastructure, shared resources and practices that communities can adopt, adapt, and extend (Chen, 2024). The skills repository provides such infrastructure: discrete, documented competencies that teachers can use individually and that the community can refine collectively.

The term “skills” is chosen deliberately. In contemporary AI development, skills refer to modular capabilities that agents invoke based on situational demands, much as expert teachers draw on repertoires of practice. By documenting KB teaching competencies with explicit triggering conditions, operational guidance, and quality criteria, the repository creates resources legible to

¹ The repository is available at <https://github.com/penn-wonderlab/kb-teaching-skills>. The repository aims to provide immediately usable heuristics for KB teaching, create a shared resource that grows with community contributions, and establish foundations for AI augmentation that preserves teacher agency.

both human practitioners and AI systems. The same skill that guides a teacher’s planning can inform an AI tool’s contextual suggestions, without requiring separate development for each.

Each skill follows a standardized documentation format aligned with emerging agent skills specifications (see [Agent Skills open standard](#)), including a description of what the skill addresses and when to invoke it, theoretical grounding in research, operational guidance with concrete strategies and language, suggestions for combining with other skills, and criteria for evaluating deployment. Anyone can modify a skill document and install it in an AI system that supports agent skills.

The repository is organized into four domains corresponding to the four KB teaching competencies articulated above. Problem Design addresses how teachers identify authentic problems. Preserving Agency addresses the challenge of preserving student agency, specifically understanding students well enough to calibrate support and avoid over-scaffolding. Discourse Facilitation addresses facilitating productive KB discourse. Epistemic Assessment addresses assessing epistemic progress. Skills are organized by the competency they most directly support, though many contribute across domains.

Domain 1: Problem Design

Problem Design guides teachers in identifying authentic KB problems with students. The skill operationalizes what makes problems theory-worthy: genuine uncertainty, potential for idea improvement, community investigation. Teachers learn to find the problematic core of topics, including what experts debate, what changed historically, and what seems obvious but is not.

Local and Global Contexts helps teachers ground problems at multiple scales. Locally, this means connecting to community and place, such as neighborhood history, regional environmental issues, and local civic questions. Globally, it means linking inquiry to challenges that transcend borders, including climate change, public health, digital ethics, and human migration, positioning students as contributors to conversations that matter beyond the classroom.

Standards Alignment helps teachers map connections between KB inquiry and curriculum standards. KB invariably exceeds curricular boundaries, but making these connections visible increases the likelihood that KB approaches satisfy accountability requirements while pursuing more ambitious epistemic goals.

Domain 2: Preserving Agency

Prior Knowledge supports diagnosing what students already understand, including productive intuitions to build on and ideas that may need revision through inquiry. This diagnostic work enables teachers to step back where students have capacity and step in where they need support.

Student Worlds guides teachers in understanding student interests, backgrounds, and concerns. Drawing on funds of knowledge research, this skill operationalizes how to learn about students’ out-of-school knowledge, not merely to make problems engaging, but to recognize the intellectual resources students bring and calibrate support accordingly. This skill may draw on rich strategies to activate cultural, linguistic, and epistemological resources students bring to KB classrooms.

Expansive Framing helps teachers position learning expansively across Engle (2006)’s five dimensions: time, place, people, topics, and role. The skill provides concrete language for opening moves, connecting moves, and stakes moves that communicate why learning matters.

Domain 3: Discourse Facilitation

Discussion Preparation supports teachers in analyzing student discourse, such as online posts and physical artifacts, to prepare for class sessions. The skill guides teachers in identifying improvable ideas, mapping productive tensions, and noticing discourse patterns that reveal opportunities for rise-above synthesis. This analysis informs facilitation without prescribing teacher moves.

Idea Improvement Facilitation offers a repertoire of talk moves for advancing community knowledge. Drawing on research on accountable talk and productive discussion (Michaels et al., 2008), the skill organizes moves by function: eliciting moves that surface ideas, connecting moves that link contributions, pressing moves that push for explanation and evidence, and participation moves that broaden engagement. Unlike traditional discussion leading, KB facilitation keeps ideas, not teacher questions, at the center, with the goal of collective idea improvement rather than convergence on correct answers.

Metadiscourse Facilitation supports teachers in leading discussions about discussion, helping students examine their own knowledge-building processes. Research by Zhang et al. (2009) and Resendes et al. (2015) demonstrates that students benefit from periodically stepping back to assess how their community is functioning: Are ideas improving? Whose contributions are being built upon? Where are the promising directions? This metacognitive work strengthens collective cognitive responsibility by making discourse patterns visible and actionable.

Domain 4: Epistemic Assessment

Student-Driven Assessment engages students in evaluating their own and their community's epistemic progress. The embedded, transformative assessment principle positions assessment as integral to knowledge building, not external to it. This skill helps teachers design assessment structures where students identify promising ideas, evaluate explanation quality, track idea development over time, and take responsibility for community knowledge advancement. Assessment becomes a knowledge-building practice rather than a teacher-owned evaluation.

Teaching Reflection supports teachers in systematically reviewing their KB practice. The skill provides frameworks for examining facilitation decisions: When did teacher moves support idea development? When did intervention close down productive uncertainty? How did problem framing shape what students investigated? This reflective practice is essential for developing the improvisational expertise KB teaching requires, helping teachers refine their judgment about when to step in and when to step back.

Connections Among Skills and Principles

The skills do not map one-to-one onto the twelve KB principles; principles are commitments, while skills are practices. Rather, each skill supports multiple principles, and each principle may be supported by multiple skills. The idea improvement facilitation skill most directly supports the knowledge-building discourse principle but also enables idea diversity through participation moves and rise-above through synthesis moves. The problem design skill supports real ideas and authentic problems but also improvable ideas because problems are designed for iteration, and epistemic agency because problems invite student theorizing.

These skills are also interconnected and designed to stack. Problem design alone produces generic problems; combined with student worlds, problems connect to student lives; combined with

expansive framing, problems are positioned expansively. Idea improvement facilitation alone provides talk move repertoires; combined with student-driven assessment, teachers can monitor discussion quality while facilitating.

A Concrete Example: Skills in Action

To illustrate how skills operate in practice, consider a unit where curriculum standards require understanding photosynthesis. A traditional approach poses “What is photosynthesis?” and proceeds to deliver the canonical explanation. KB teaching proceeds differently.

The teacher draws on the student worlds skill to surface relevant student experience. In this class, several students help their families grow vegetables; one reports that her grandmother’s tomatoes perform differently depending on garden placement. Another student has encountered news coverage of food shortages. These observations constitute productive starting points for inquiry.

The problem design skill guides the teacher in working with students to formulate authentic questions: Why do plants grow better under certain conditions? What do plants require? Rather than presenting a predetermined problem, the teacher creates conditions for students to generate questions from their own observations. The teacher maintains awareness that curriculum standards require understanding photosynthesis, and recognizes that student questions about plant growth can lead to this understanding through inquiry rather than transmission.

The local and global contexts skill extends the investigation beyond immediate experience. Students with gardening knowledge develop theories about optimal growing conditions. The student concerned with food shortages raises questions about cultivating plants for difficult environments. Local experience connects to global challenges in food security and climate adaptation.

What emerges is a problem space rather than a single teacher-designed problem. Students pursue related questions about plant needs, growing conditions, and possibilities for intervention. Photosynthesis becomes conceptual territory students must engage to address their own questions, rather than content delivered independent of student purpose.

This example illustrates core features of the framework: skills are triggered and stack together as teaching unfolds; students contribute authentic problems grounded in their experience; and teachers maintain curricular awareness while preserving space for student-directed inquiry.

Why This Matters for the Knowledge Building Community

KB has demonstrated effectiveness across contexts and age levels, yet remains challenging to implement at scale. I suggest that one barrier has been insufficient infrastructure for KB teaching practice. Teachers have had access to KB principles and tools like Knowledge Forum, but less access to the operational competencies that enable principle-informed practice. Great work has taken place in many education systems to support KB teaching, but artifacts and stories about KB teaching still need to be elevated to become primary objects of inquiry in the KB community.

The skills repository mitigates this gap. By decomposing KB teaching into learnable components, documenting them in shareable form, and designing for progressive development, the repository creates infrastructure that the community can use and extend. Expressing the craft of KB teaching as skills allows the development of principled practical knowledge, making skills explicit, learnable, and improvable by the community.

Following Chen (2024), I view this repository as a starting point for community infrastructuring rather than a finished product. The current set of skills represents an initial, biased synthesis of research and practice. The KB community spans contexts, grade levels, and subject areas that exceed any single person's experience. The repository structure enables contributions: new skills, adaptations for specific contexts, translations, and refinements based on classroom use.

Foundations for Responsible Augmentation

The explicit documentation of KB teaching skills creates a secondary affordance: foundations for AI augmentation. Because the skills articulate what effective KB teaching involves, including what teachers should notice, what moves are available, and what counts as quality, they provide specifications that AI systems could eventually draw upon. An AI tool supporting discourse facilitation, for instance, could draw on the idea improvement facilitation skill's repertoire of talk moves to offer contextual suggestions.

Recent research demonstrates that AI can enhance rather than undermine teacher agency in KB contexts when thoughtfully integrated. Hong et al. (2025) found that generative AI support enabled more elaborated, synthesis-oriented discourse in teacher communities and significantly enhanced professional agency, outcomes that did not emerge without AI support. This finding suggests that the concern should not be whether to integrate AI, but how to do so in ways that augment rather than supplant teacher judgment.

Consider a teacher preparing a unit on climate change. She loads the problem design skill into Claude, describes her curricular goals, and shares what she knows about her students' interests. The system draws on the skill to help identify the problematic core of the topic, suggest connections to student worlds, and surface possibilities for local and global contextualization—all grounded in KB pedagogy rather than generic lesson planning. The teacher decides which directions to pursue; the AI expands what she has to work with. Importantly, the AI system should make the process transparent (following progressive disclosure mechanisms) so the teacher can observe the activation of specific skills and have opportunities to learn, react, and reflect.

The skills framework does not itself constitute AI augmentation; rather, it creates the explicit knowledge base that responsible augmentation requires. This ordering, human infrastructure first and AI enhancement second, keeps teacher agency central while enabling technological support.

Limitations and Tensions

This framework rests on assumptions that warrant acknowledgment and future investigation.

Decomposition risks fragmentation. The teaching practice literature that grounds this work emphasizes that decomposition is a learning strategy, not a claim about the ultimate nature of teaching (Grossman, Compton, et al., 2009). Expert teaching involves integrated, improvisational performance that exceeds the sum of component skills. Whether teachers who develop skills individually can integrate them effectively remains an empirical question.

Codification risks rigidity. By documenting skills explicitly, I create resources that could become prescriptive rather than generative. The skills are intended as repertoires and heuristics, not scripts, but documented resources can be used in ways designers did not intend. Professional development approaches that use these skills will need to maintain space for teacher adaptation and contextual judgment.

Infrastructure does not guarantee use. Chen (2024) distinguishes between creating infrastructure and achieving adoption. The skills repository provides resources, but whether teachers find them useful, how they adapt them, and whether adaptation strengthens or weakens their effectiveness are questions the repository itself cannot answer. Ongoing community engagement and empirical study are essential. This is essentially what Chen (2024) argued for: the continual work by teachers to create their own functional infrastructure.

The framework privileges some teachers over others. Novice teachers may benefit most from explicit skill decomposition; experienced teachers may find it unnecessary or constraining. The progressive stackability design attempts to address this variation, but teachers at different developmental stages will likely relate to the framework differently.

Conclusion

KB asks much of teachers: designing authentic problems, facilitating productive discourse, assessing epistemic progress, and preserving student agency, all while navigating the real-time complexity of classroom life. Supporting teachers in this work requires understanding teaching as professional practice and KB teaching as a distinctive form of that practice.

I have presented a framework of stackable skills grounded in research on teaching practice, teacher noticing, and KB pedagogy. The framework decomposes KB teaching into learnable components that teachers can develop individually and integrate progressively. Organized into four domains (problem design, preserving agency, discourse facilitation, and epistemic assessment), the skills provide operational guidance for enacting KB principles in classroom settings.

This skills repository offers workable infrastructure for the KB community: shared resources that teachers can adopt, that the community can extend, and that create foundations for AI augmentation preserving teacher agency. The path forward involves both expanding the repository through community contributions and investigating how teachers develop these skills individually and in combination.

KB's vision of students as knowledge creators depends on teachers capable of creating the conditions for knowledge building. This framework aims to support those teachers, enhancing their capacity without diminishing their judgment, and building infrastructure that can sustain KB teaching across contexts.

References

Bielaczyc, K., & Ow, J. (2014). Multi-player epistemic games: Guiding the enactment of classroom knowledge-building communities. *International Journal of Computer-Supported Collaborative Learning*, 9(1), 33–62. <https://doi.org/10.1007/s11412-013-9186-z>

Chen, B. (2024). A framework for infrastructuring sustainable innovations in education. *Journal of the Learning Sciences*. <https://doi.org/10.1080/10508406.2024.2328137>

Chen, B., & Hong, H.-Y. (2016). Schools as knowledge-building organizations: Thirty years of design research. *Educational Psychologist*, 51(2), 266–288. <https://doi.org/10.1080/00461520.2016.1175306>

Chuy, M., Zhang, J., Scardamalia, M., & Bereiter, C. (2011). Getting started in Knowledge Building. In *Knowledge building summer institute 2011*. University of Toronto.

- Engle, R. A. (2006). Framing interactions to foster generative learning: A situative explanation of transfer in a community of learners classroom. *Journal of the Learning Sciences*, 15(4), 451–498. https://doi.org/10.1207/s15327809jls1504_2
- Grossman, P. (2011). Framework for teaching practice: A brief history of an idea. *Teachers College Record*, 113(12), 2836–2843.
- Grossman, P., Compton, C., Igra, D., Ronfeldt, M., Shahan, E., & Williamson, P. (2009). Teaching practice: A cross-professional perspective. *Teachers College Record*, 111(9), 2055–2100.
- Grossman, P., Hammerness, K., & McDonald, M. (2009). Redefining teaching, re-imagining teacher education. *Teachers and Teaching*, 15(2), 273–289. <https://doi.org/10.1080/13540600902875340>
- Hong, H.-Y., Chen, P.-Y., Chang, Y.-H., & Tseng, S.-C. (2025). AI-supported idea-developing discourse to foster professional agency within teacher communities for STEAM lesson design in knowledge building environment. *Computers & Education*, 105241. <https://doi.org/10.1016/j.compedu.2025.105241>
- Kavanagh, S. S., Metz, M., Hauser, M., Fogo, B., Taylor, M. W., & Carlson, J. (2020). Practicing responsiveness: Using approximations of teaching to develop teachers' responsiveness to students' ideas. *Journal of Teacher Education*, 71(1), 94–107. <https://doi.org/10.1177/0022487119841884>
- Michaels, S., O'Connor, C., & Resnick, L. B. (2008). Accountable talk in the classroom: The uses and varieties of classroom talk. *Studies in Philosophy and Education*, 27(4), 283–297. <https://doi.org/10.1007/s11217-007-9085-3>
- Resendes, M., Scardamalia, M., Bereiter, C., Chen, B., & Halewood, C. (2015). Group-level formative feedback and metadiscourse. *International Journal of Computer-Supported Collaborative Learning*, 10(3), 309–336. <https://doi.org/10.1007/s11412-015-9219-x>
- Scardamalia, M. (2002). Collective cognitive responsibility for the advancement of knowledge. In B. Smith (Ed.), *Liberal education in a knowledge society* (pp. 67–98). Open Court.
- Scardamalia, M., & Bereiter, C. (2006). Knowledge building: Theory, pedagogy, and technology. In K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 97–118). Cambridge University Press.
- Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, 57(1), 1–22. <https://doi.org/10.17763/haer.57.1.j463w79r56455411>
- van Es, E. A., & Sherin, M. G. (2002). Learning to notice: Scaffolding new teachers' interpretations of classroom interactions. *Journal of Technology and Teacher Education*, 10(4), 571–596.
- Zhang, J., Scardamalia, M., Reeve, R., & Messina, R. (2009). Supporting collective ideation: Idea building in knowledge building communities. *Educational Technology Research and Development*, 57(4), 467–487. <https://doi.org/10.1007/s11423-009-9116-y>